POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Competition and Carbon

What determines wind deployment?
What technology is the competitor?
What are the impacts on mitigiaton?

Nico Bauer, Gunnar Luderer, Robert Pietzcker

Climate Change Impacts and Integrated Assessment Workshop
Snowmass, Colorado
July 22-23, 2013

Content

- Introduction
- Carbon tax and sensitivity of technology parameters
- Models and scenarios
  - No Policy, Flagship
  - noCCS/noNuc
  - Others
- Results
  - Scale and structure of electricity generation
  - CO_2 emissions and sectoral fossil fuel leakage
  - What are the crucial sensitivities?
- Summary

Participating models – General features

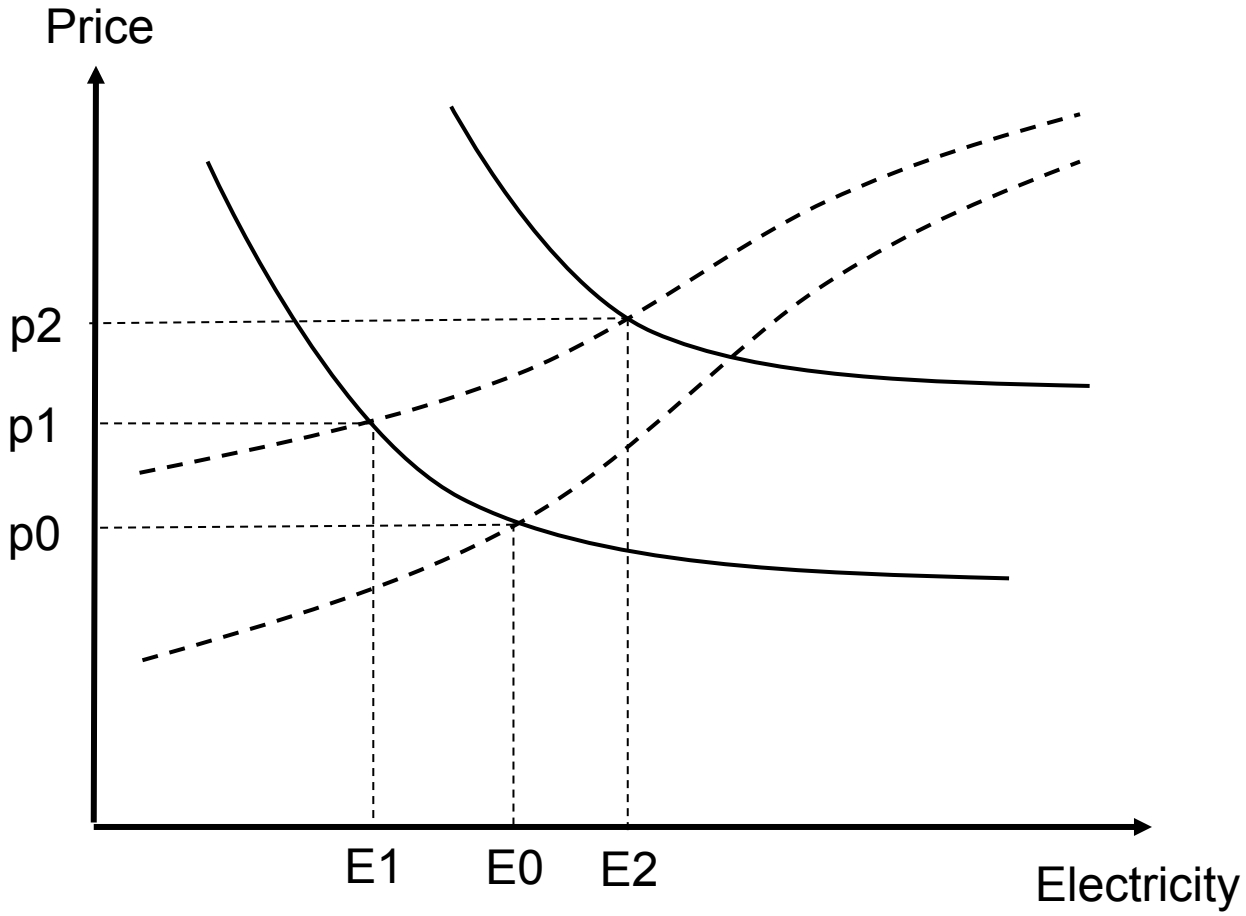
	AIM-CGE	DNE21+	GCAM	IMAGE	MESSAGE	POLES	ReMIND	WITCH
Time Horizon	2050	2100	2100	2100	2100	2100	2100	2100
Model type	CGE	ESM	ESM	ESM	ESM	ESM	Hybrid	Hybrid
Dynamic Structure	RD	IT	RD	RD	IT	RD	IT	IT
Wind off-shore				X	X	X		X
Endogenous electricity demand	X	X	X	X	X	X	X	X
Endogenous technological learning							X	X

Scenarios

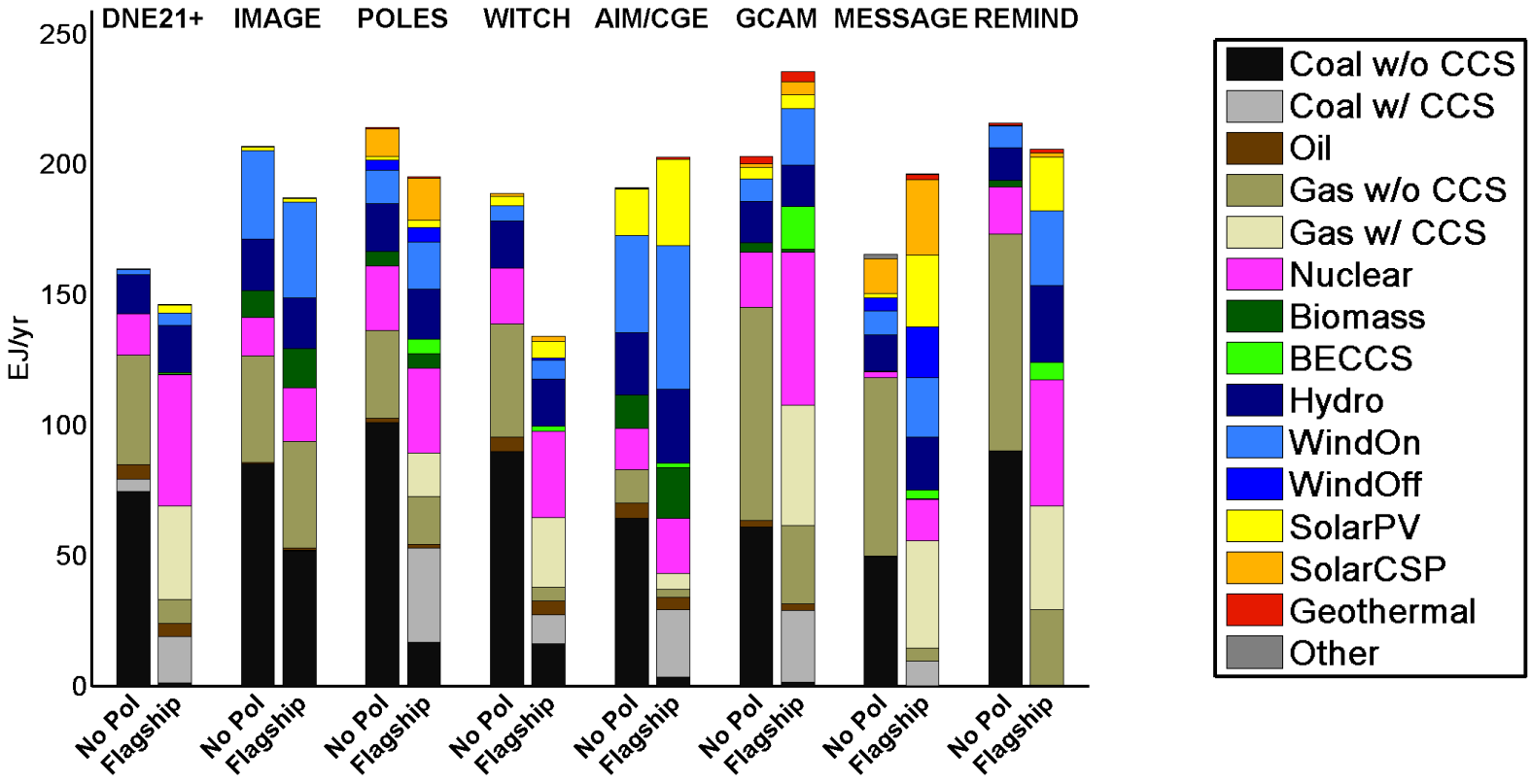
	Wind Resource	Wind Cost	Carbon Policy	Integration Cost/Limit	Nuke/CCS Availability
1. Flagship	Model's existing supply curve	Standard	Tax	Standard	All tech
2. New Wind	NREL supply curve, new	Standard	Tax	Standard	All tech
3. No Policy	Model's existing supply curve	Standard	None	Standard	All tech
4. RE	Model's existing supply curve	Standard	Tax	Standard	Nuke phase-out, no CCS
5. Generous RE Integration	Model's existing supply curve	Standard	Tax	Relaxed	All tech
6. Strict RE Integration	Model's existing supply curve	Standard	Tax	Tightened	All tech
7. Low Cost	Model's existing supply curve	Low	Tax	Standard	All tech
8. High Cost	Model's existing supply curve	High	Tax	Standard	All tech

The impact of imposing a carbon tax on global power sector and emissions

The impact of a C-tax on the electricity market



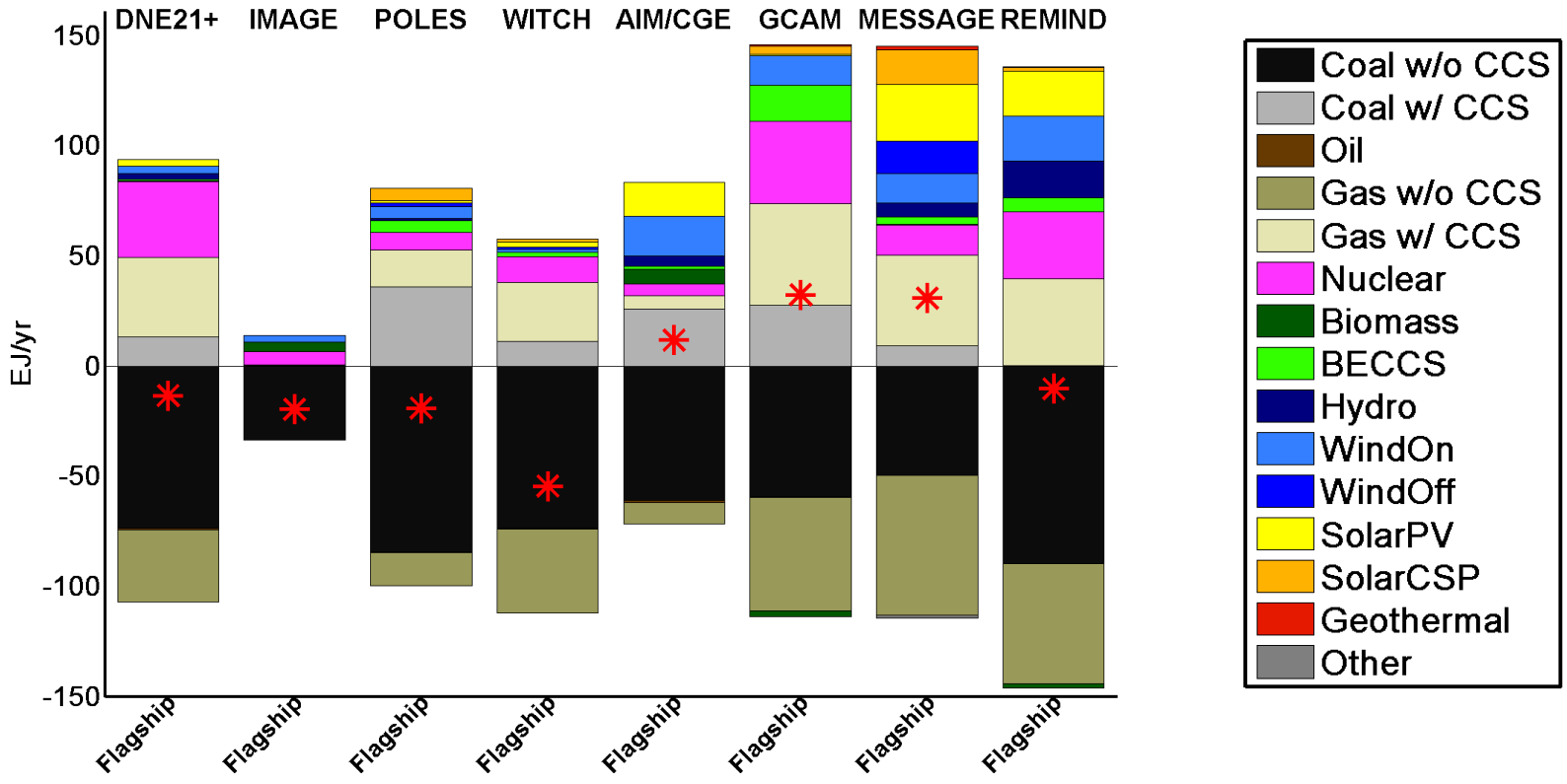
Global Electricity in 2050



- Total grows (2010: 77EJ/yr)
- Wind is competitive in NoPol
- Solar only in some models by 2050

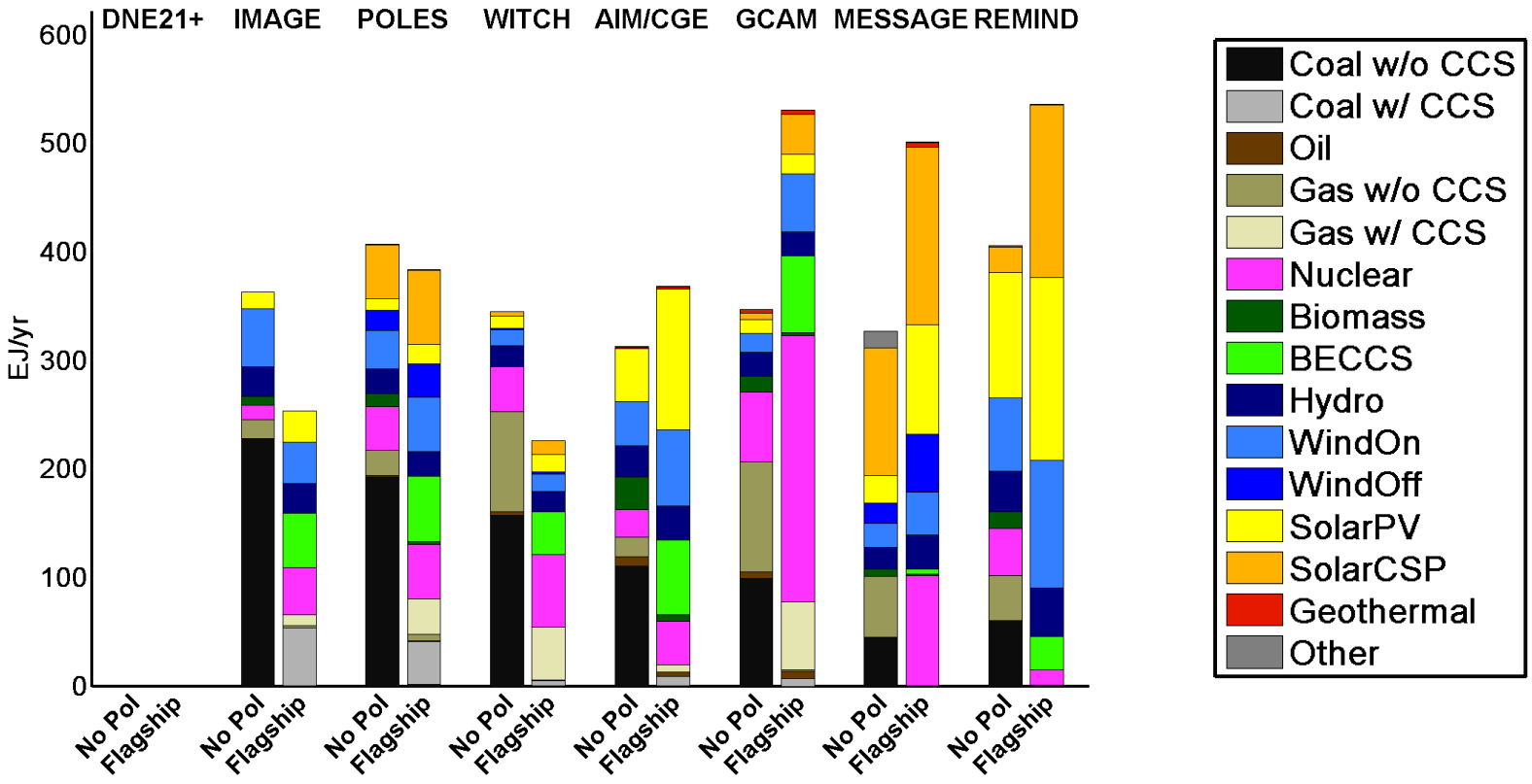
- Tax induces more wind deployment
- Up to 50EJ/yr
- Some decrease elec., but do not boost wind (DNE, IMAGE, POLES, WITCH)

Differences in Global Electricity in 2050



- Coal and gas reduced and with CCS
- MESSAGE, AIM/CGE, ReMIND follow a renewable strategy

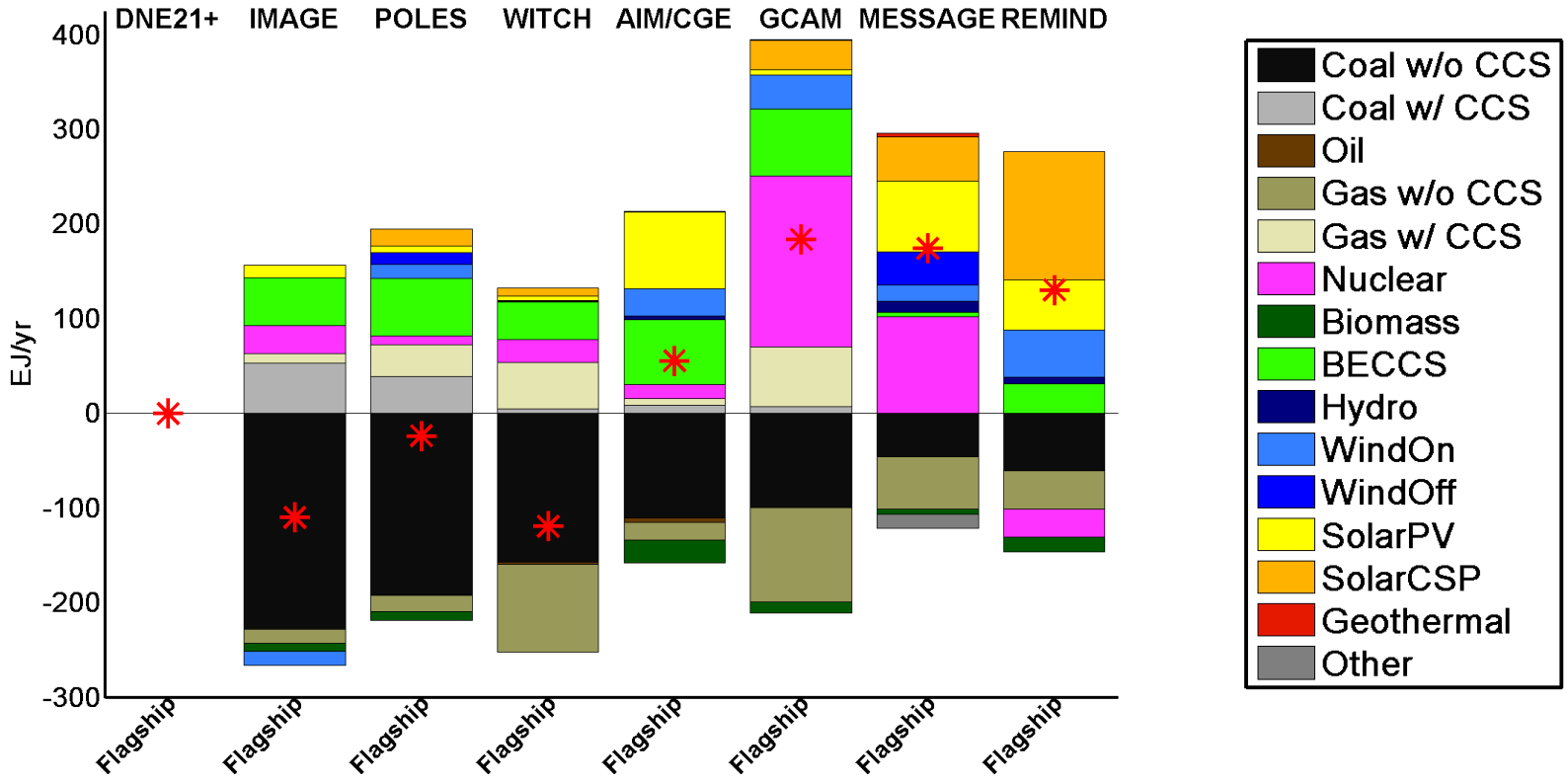
Global Electricity in 2100



- Electricity keeps on growing
- W&S gains significant share in most No Policy scenarios

- C-tax boosts power in 4/7 models
- Also wind, but share is limited
- Electricity reduction comes with little W&S deployment; IMAGE even wind reduction

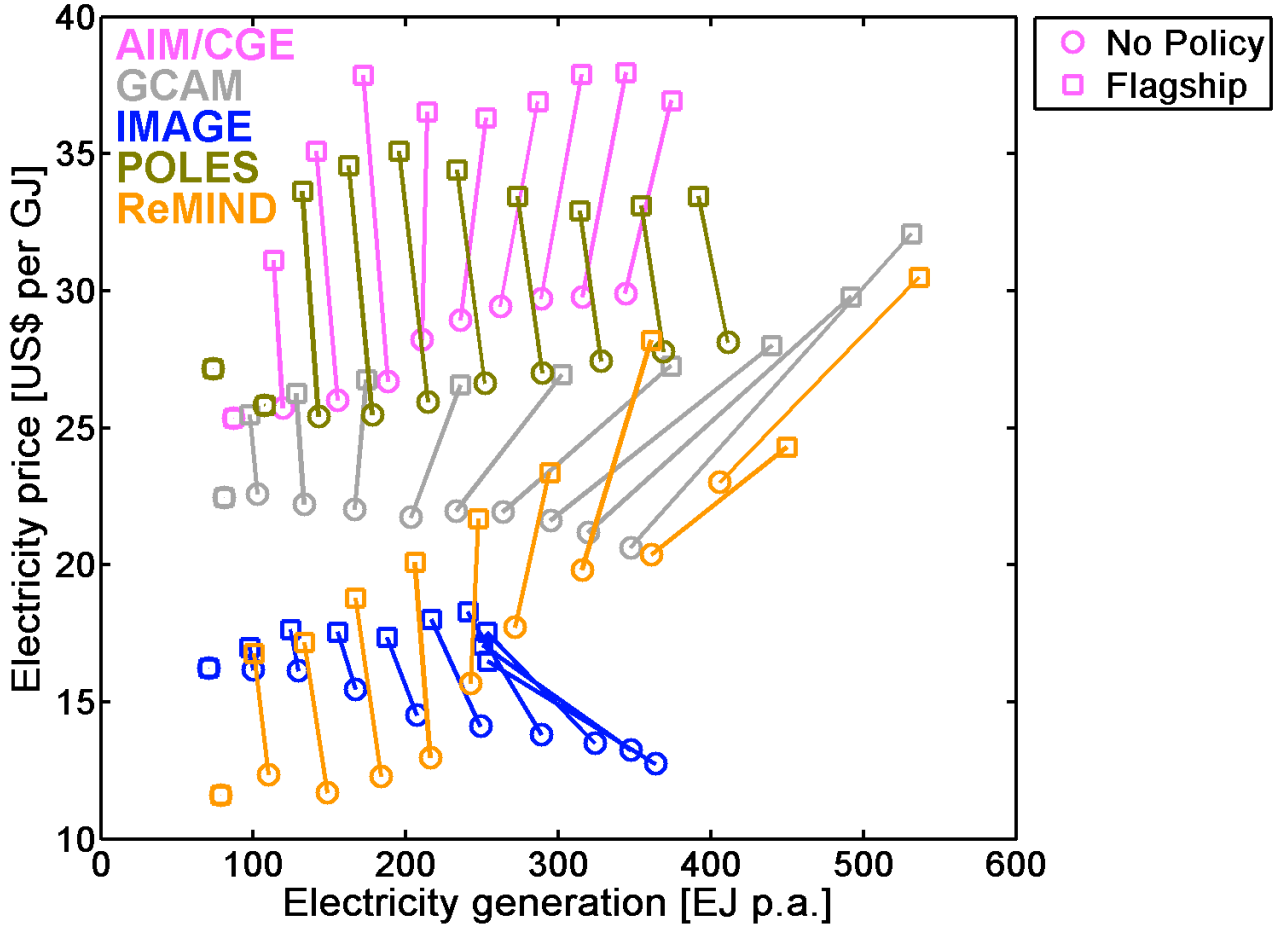
Differences in Global Electricity in 2100



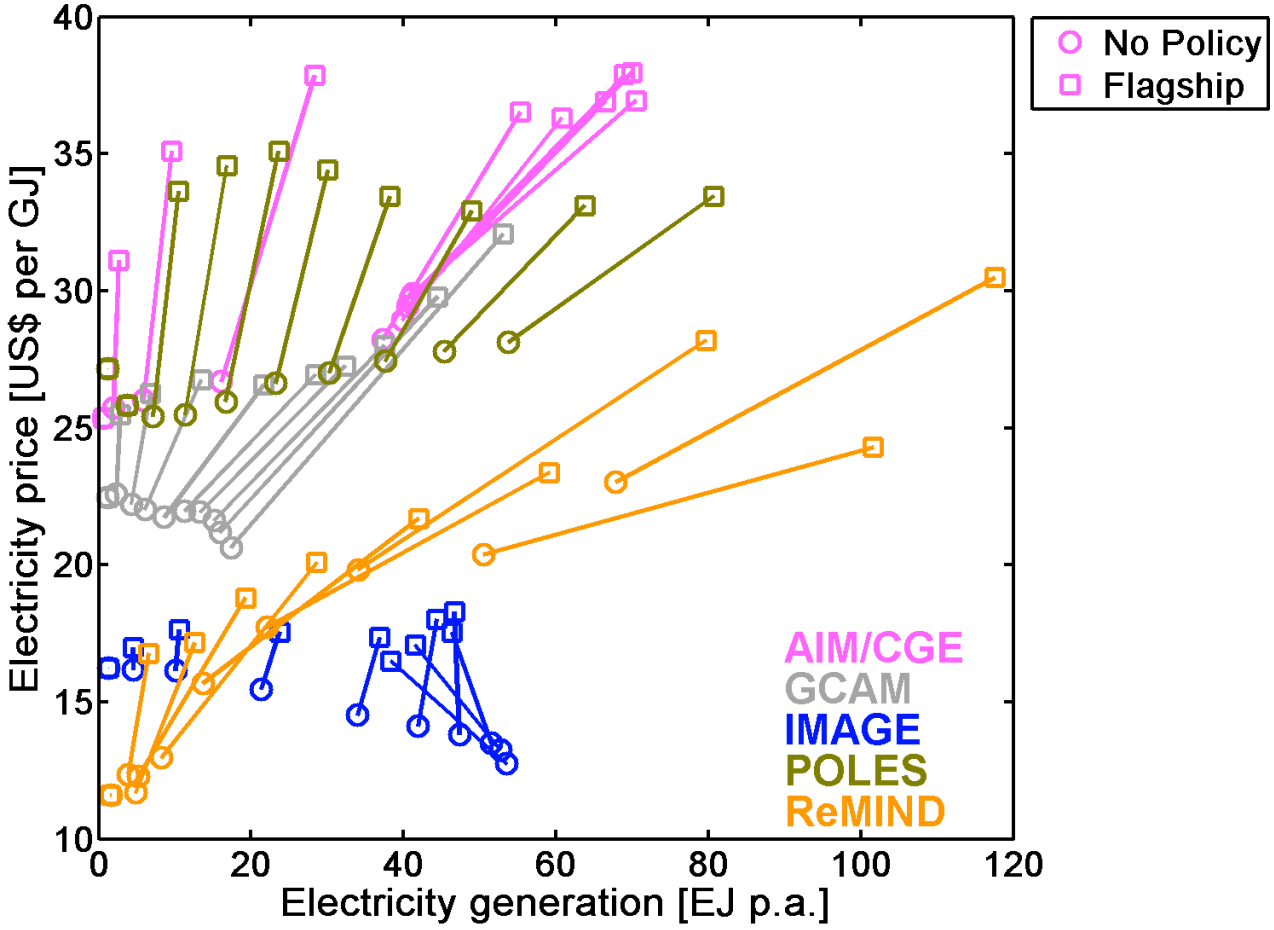
- Electricity keeps on growing
- Wind gains significant share in NoPol

- C-tax boosts power in 4/7 models
- Also wind, but share is limited
- Electricity reduction comes with little wind deployment; IMAGE even reduction

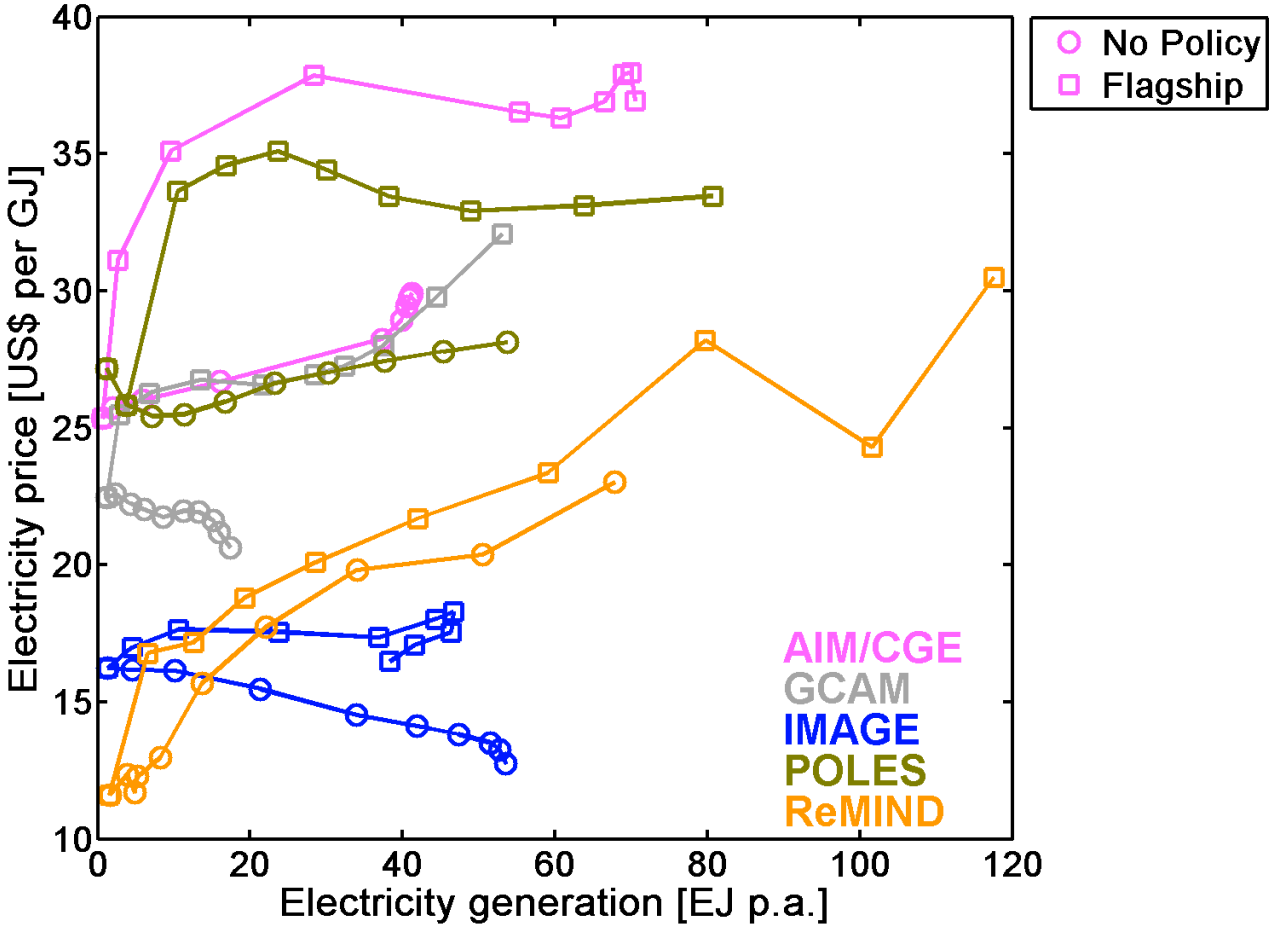
Carbon tax and electricity market



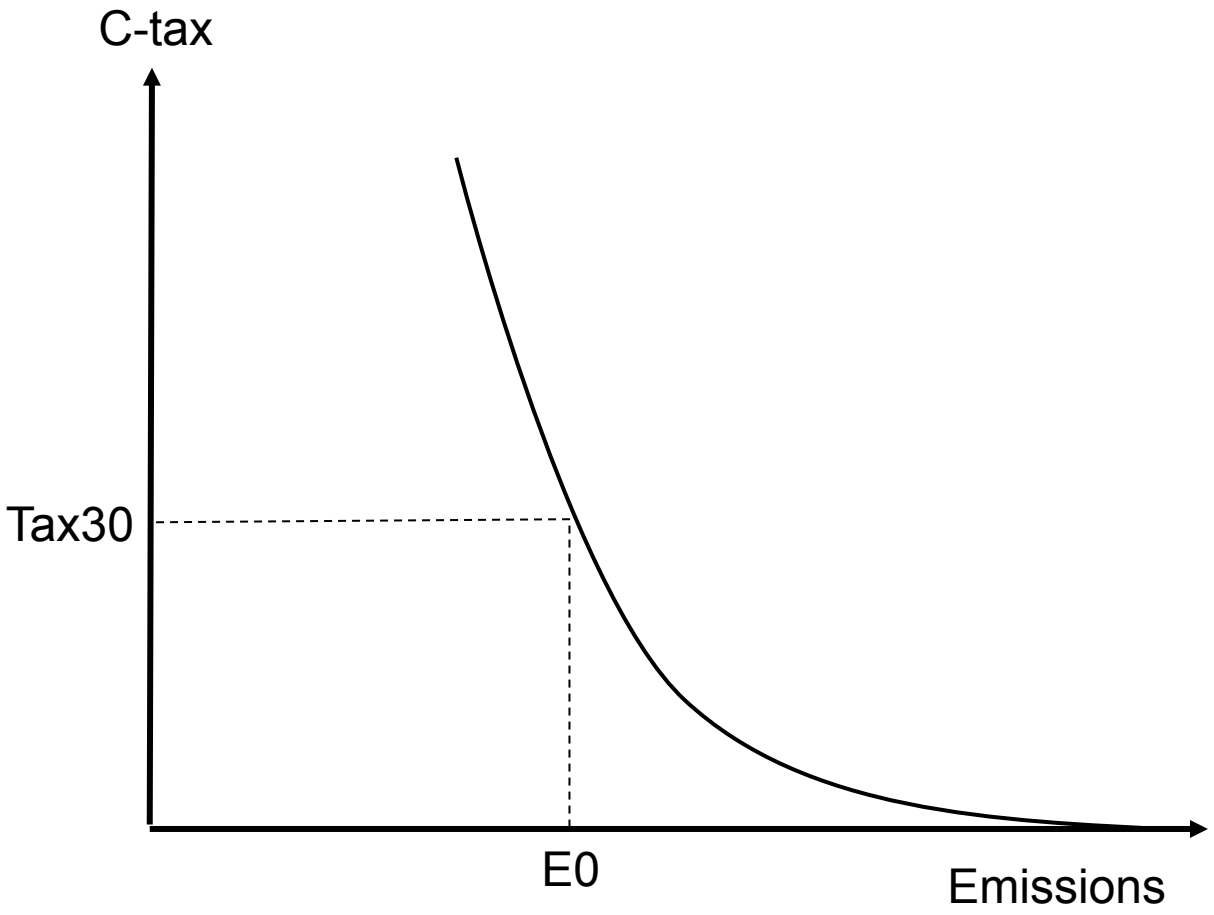
Carbon tax and electricity market



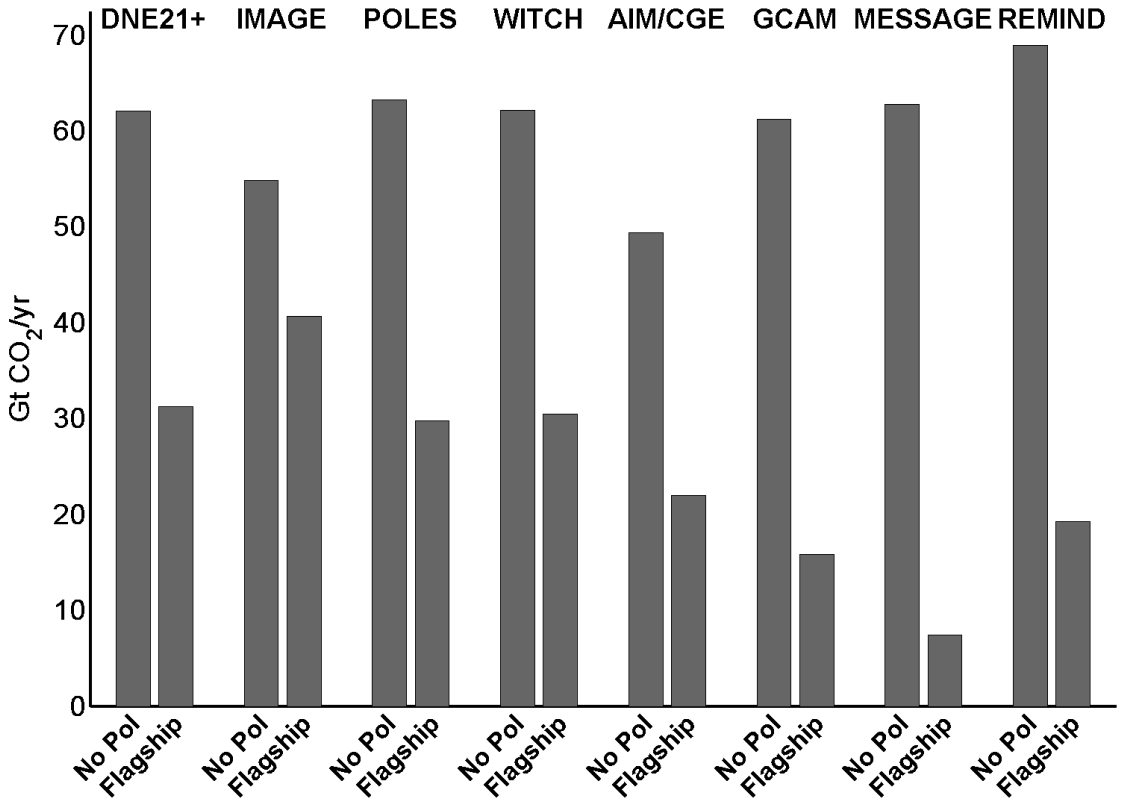
Carbon tax and electricity market



Results – the impact of a carbon tax

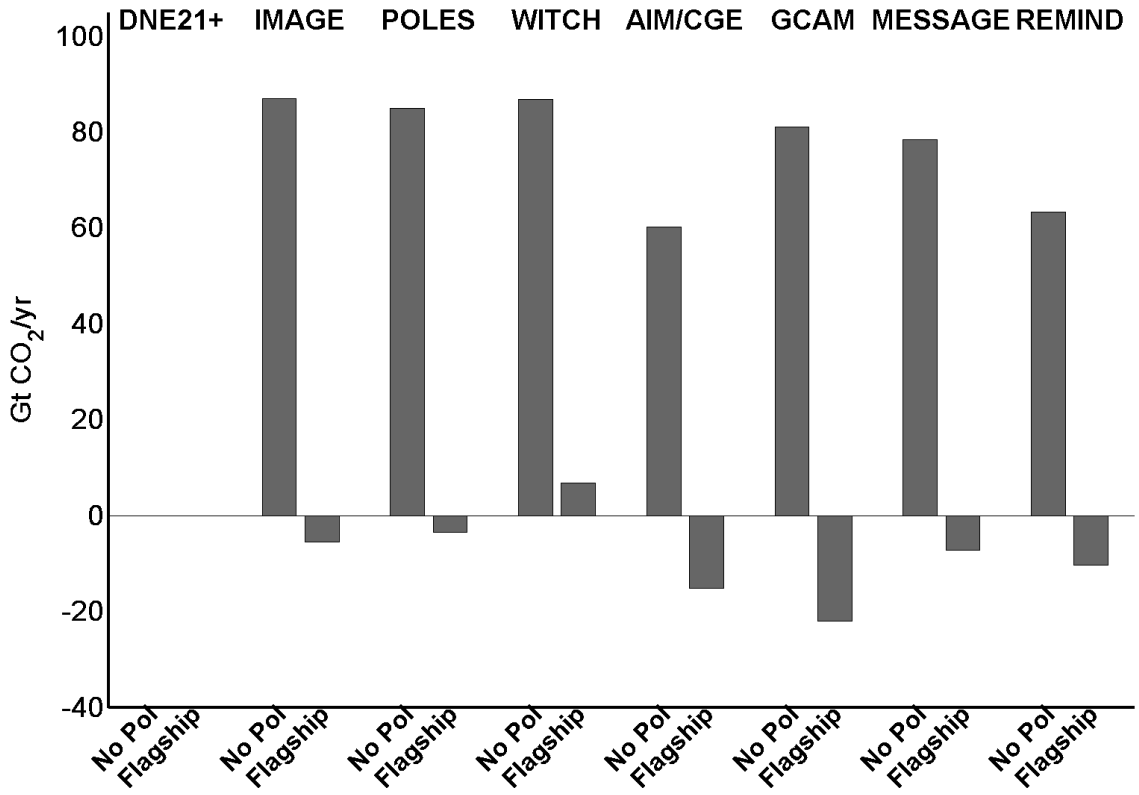


Global CO_2 Emissions in 2050



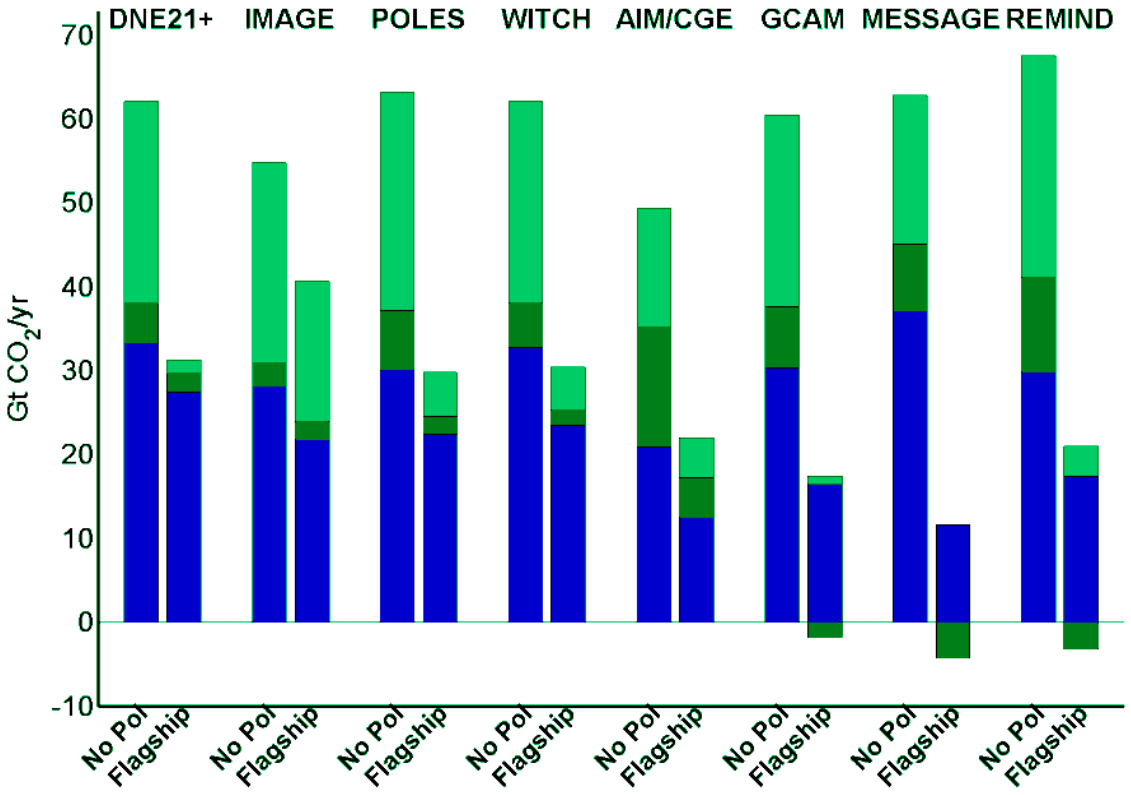
- Models with elec. decrease show CO_2 emissions to ~30GtCO_2 @ 130$/t$CO_2$
- Models with electricitiy boost show stronger sensitivity

Global CO_2 Emissions in 2100



- In the longer term the differentiation is less powerful to explain sensitivity
- The tax is sufficient to induce negative net CO_2 emission

Global CO_2 Emissions by sector in 2050

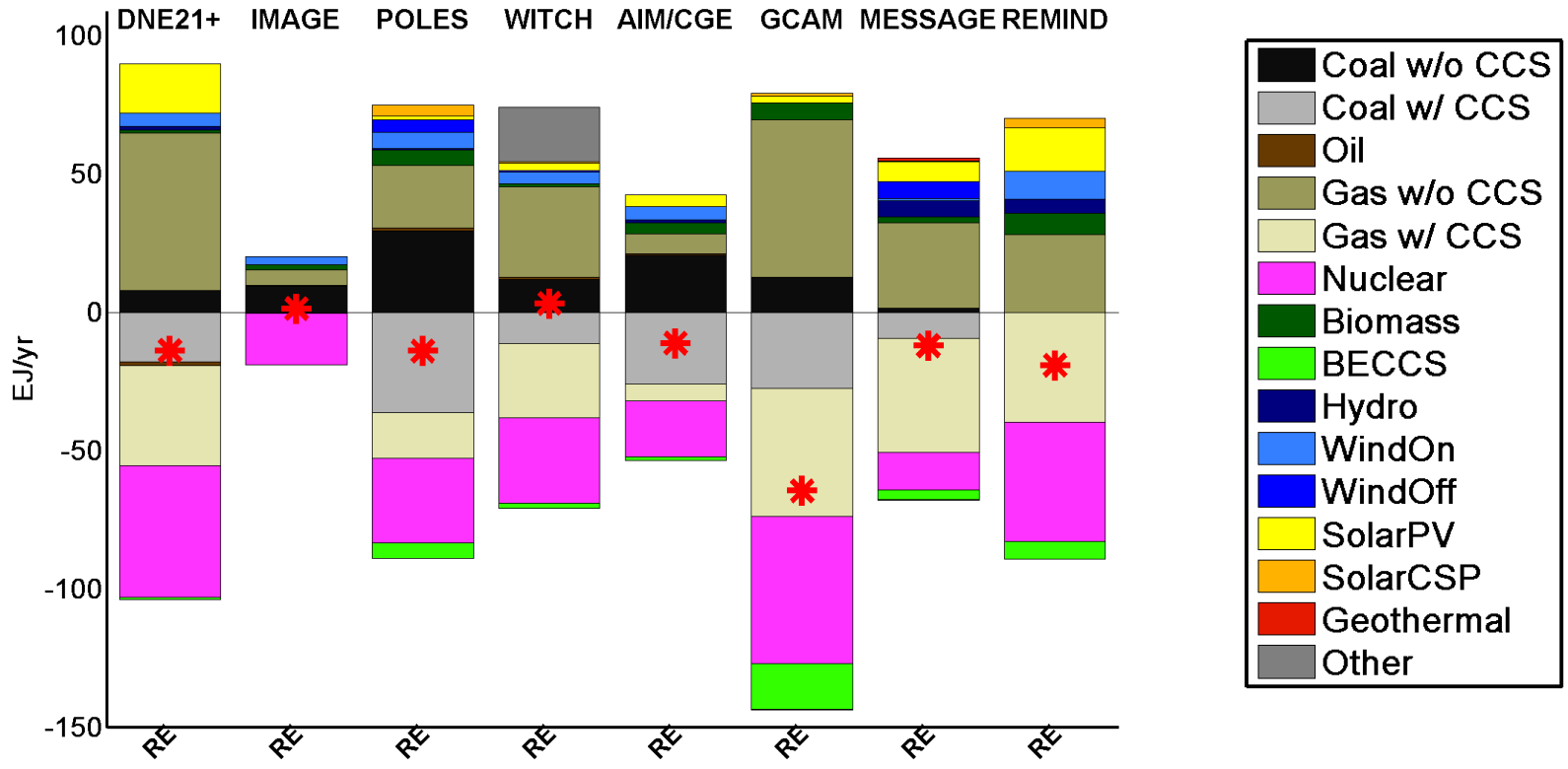


Note: AIM/CGE did not report supply emissions.
Hence, correction applied.

- Electricity sector is strongly decarbonized; especially in electrifying models
- Negative emissions in non-electric supply
- Demand side still shows significant residual emissions

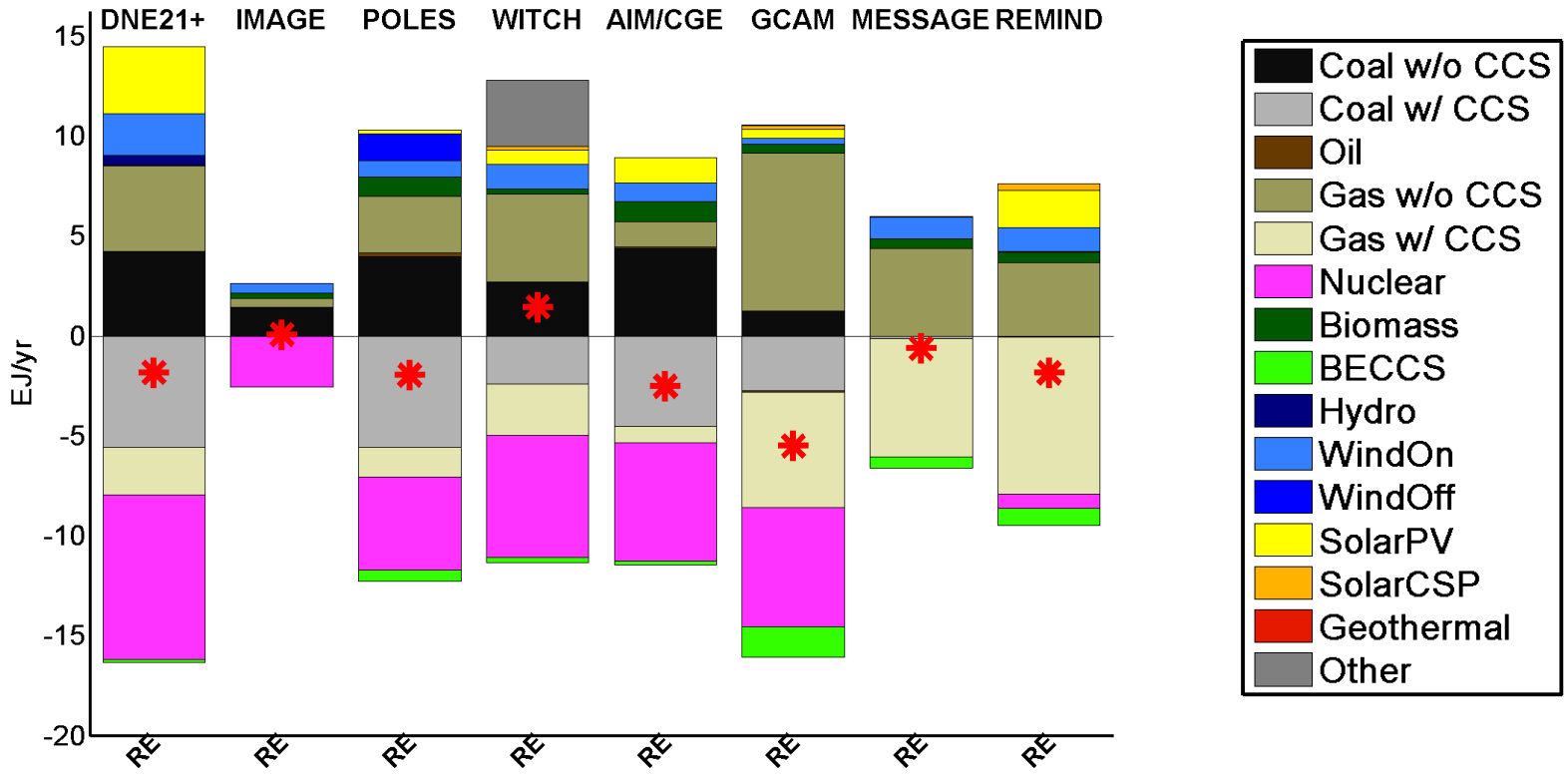
The impact of NoNuc&NoCCS on the renewables and CO_2 emissions

Differences in Global Electricity in 2050 to Flagship



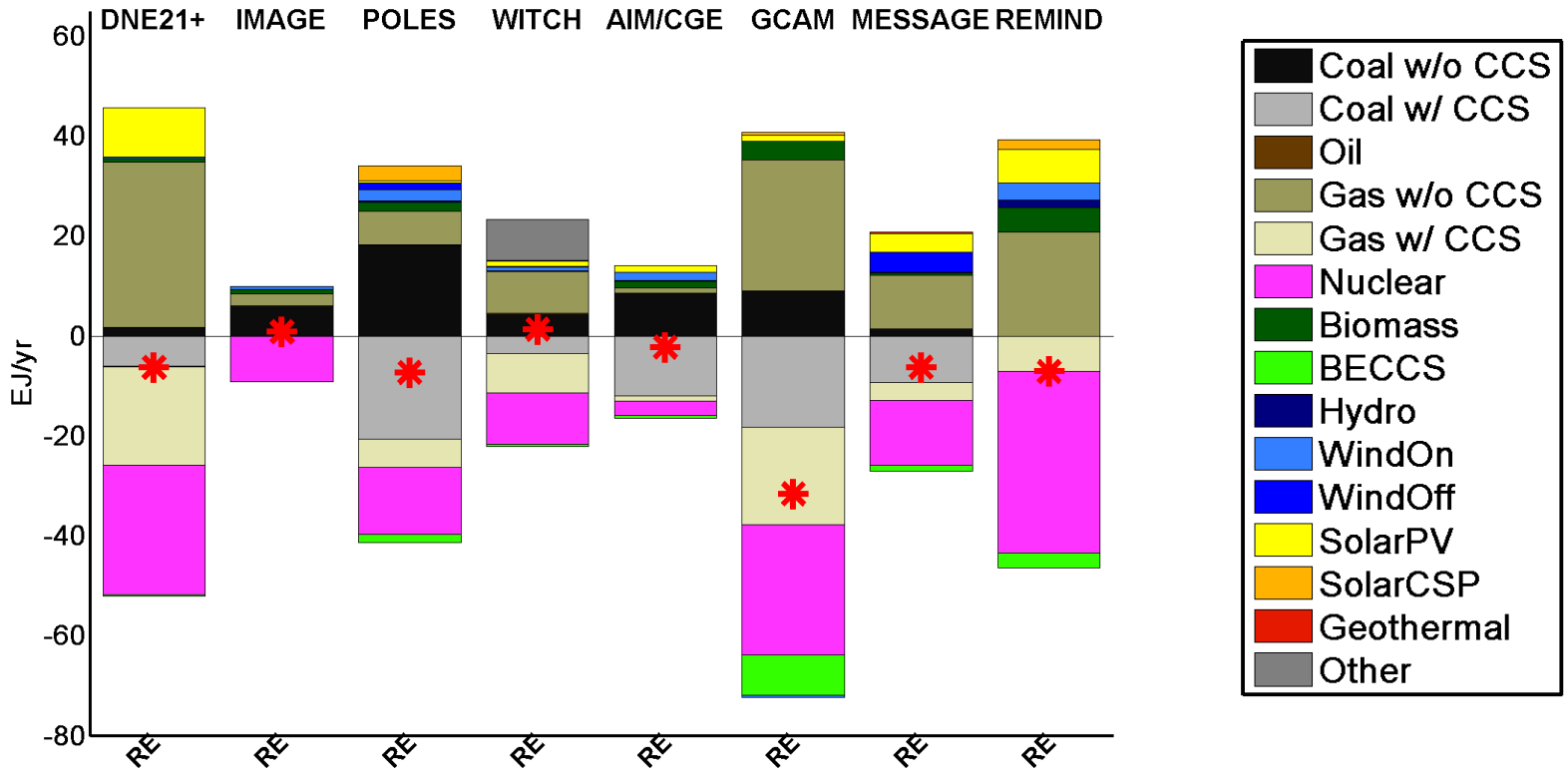
- Mostly electricity production is reduced (not IMAGE and WITCH)
- The gap is mainly closed by fossils not used with CCS anymore; slightly biased towards gas
- Renewables (incl. Bio) partially compensate missing nuclear power
  - GCAM shows smallest Renewable change, ReMIND highest

Differences in US Electricity in 2050 to Flagship



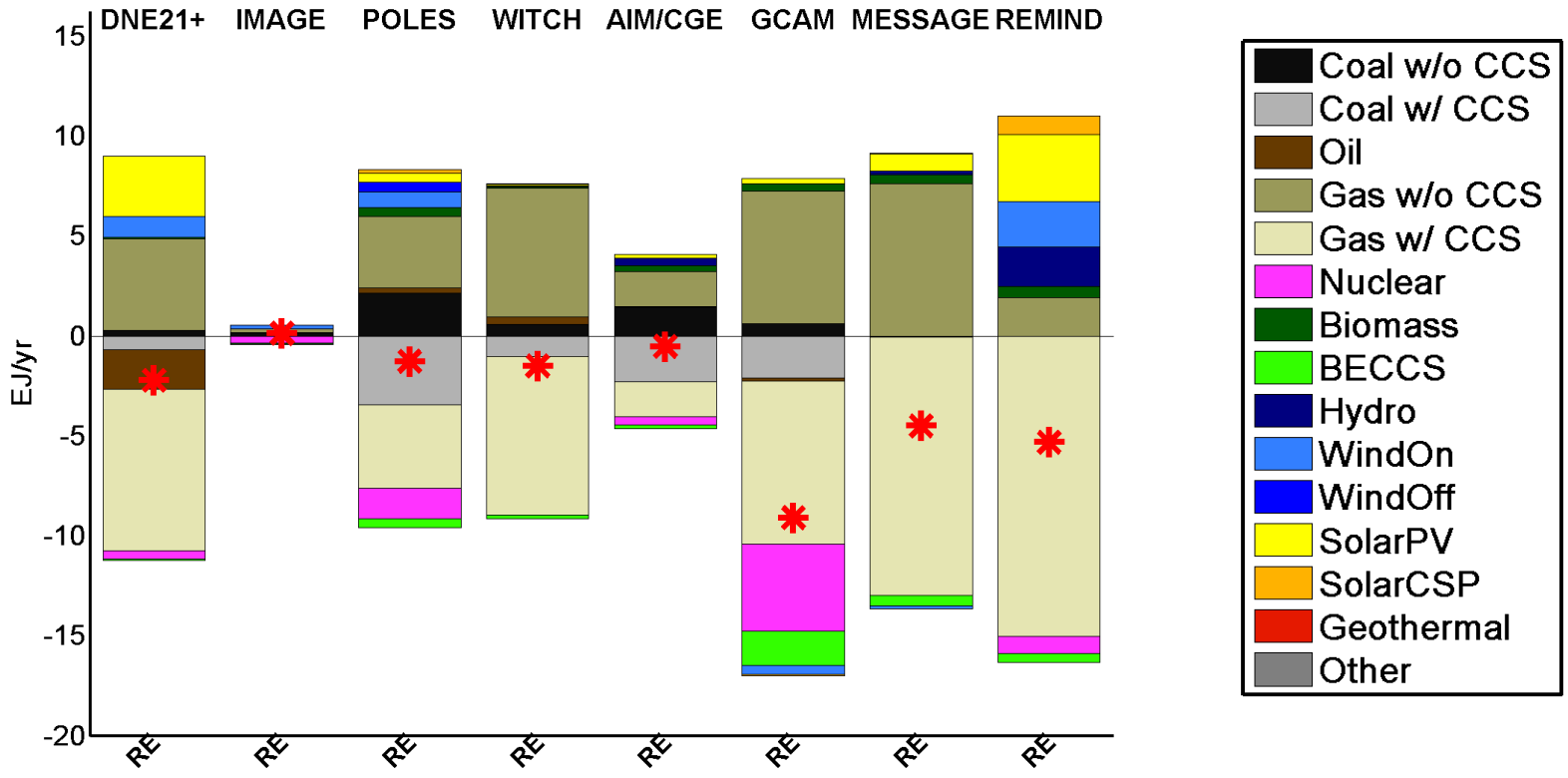
- The US basically mirrors the global effect

Differences in Asia Electricity in 2050 to Flagship



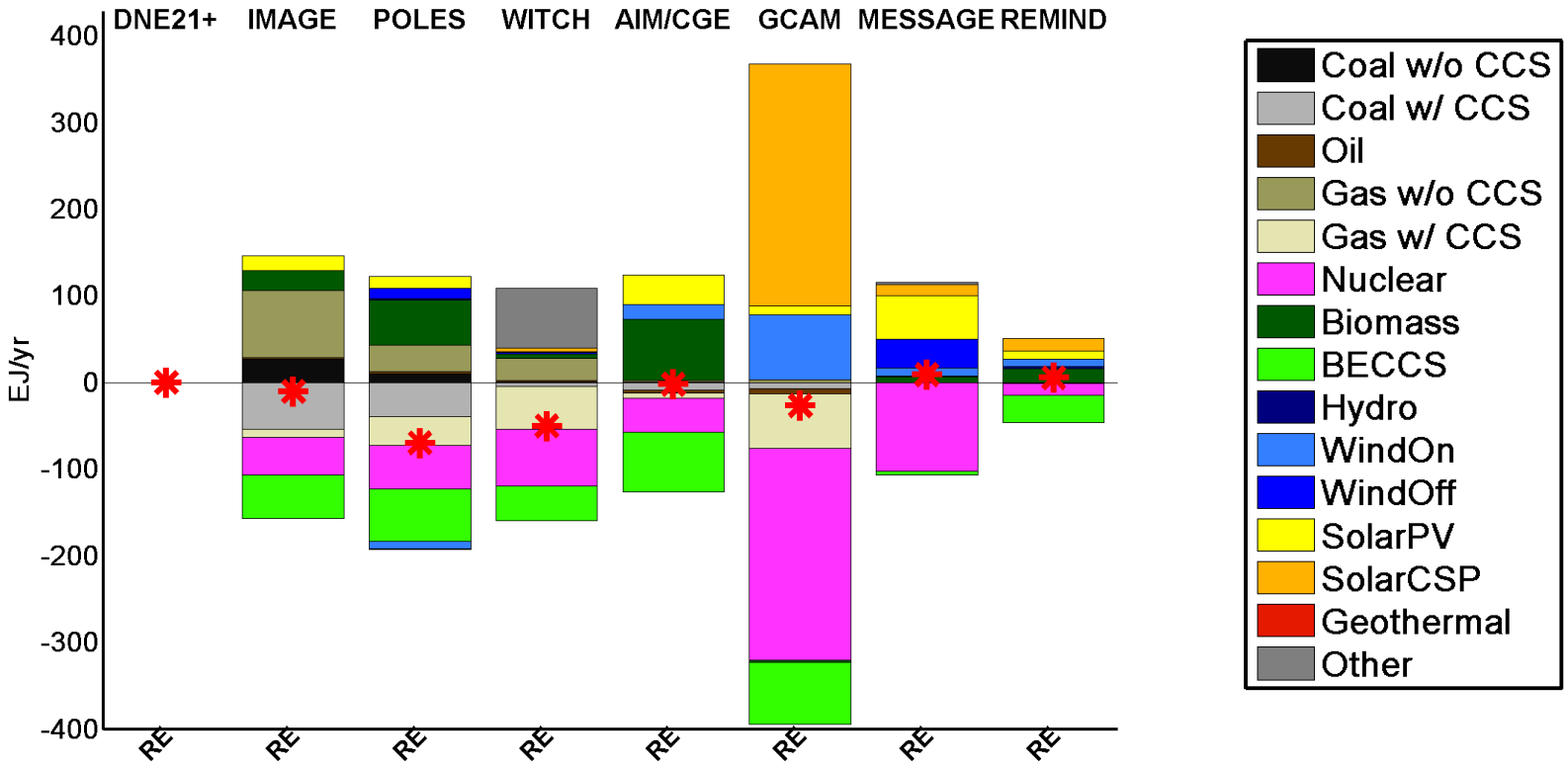
- In Asia gas compensation is large
- Renewable compensation is relatively small
- However, the missing nuclear is relatively large (GCAM, ReMIND, DNE21)

Differences in MAF Electricity in 2050 to Flagship



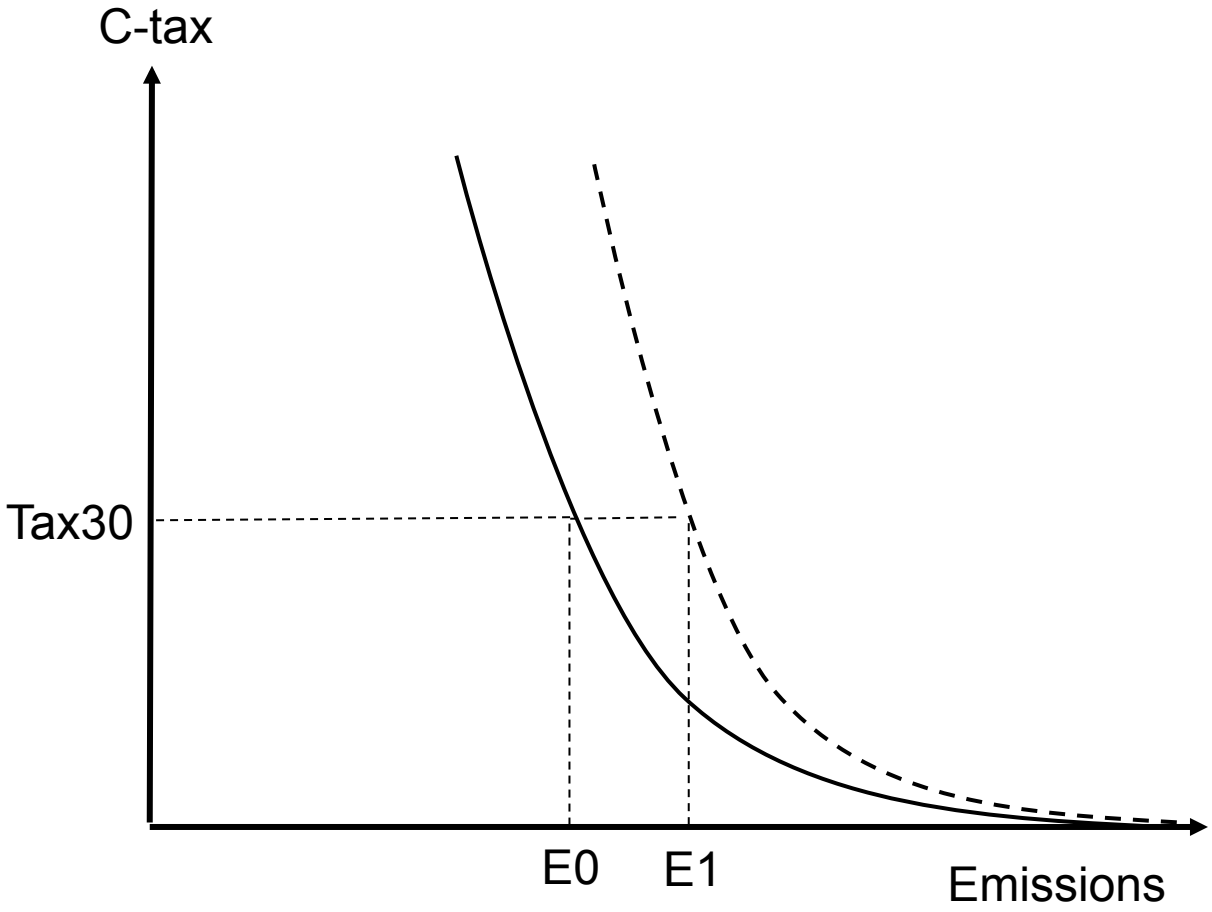
- In MAF gas fills most ot the gap; nuclear is not as significant
- In ReMIND renewables deployment saves gas for export at high price

Differences in Global Electricity in 2100 to Flagship

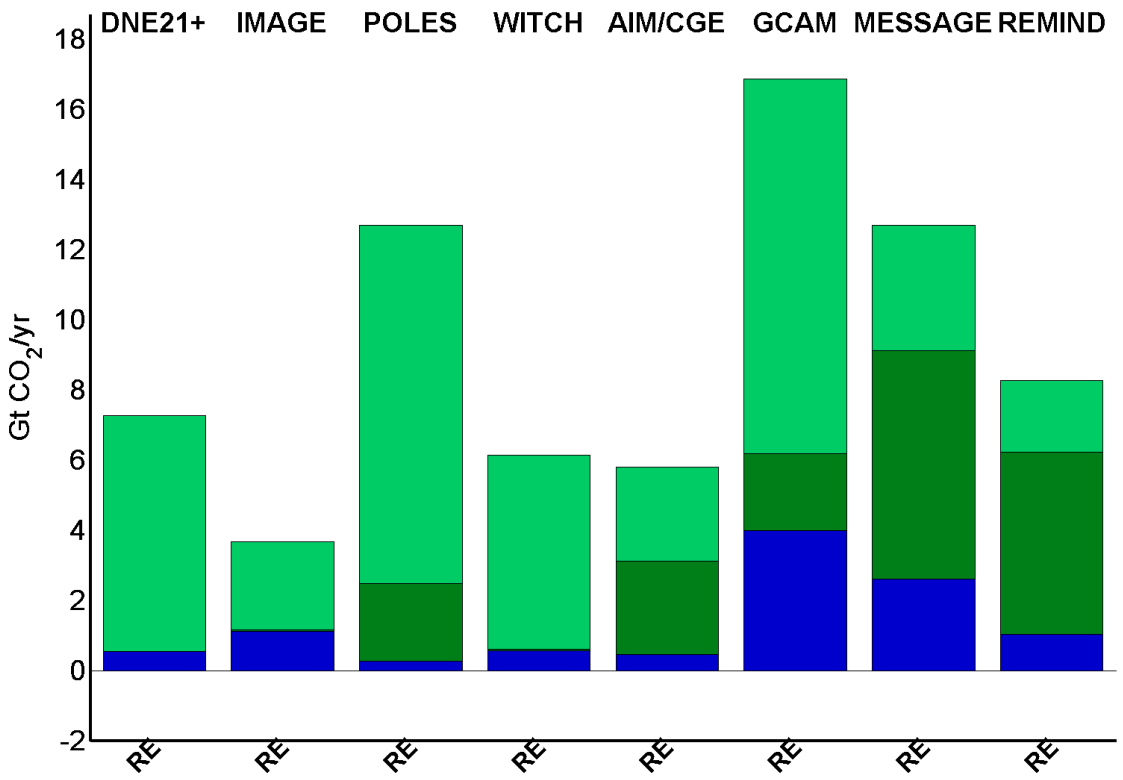


- Most models show no change in total electricity (not POLES, WITCH)
- Nuclear gap filled by renewables in GCAM and MESSAGE
- The CSP share in GCAM comes mainly from MAF, India, and China

Results – the impact of a carbon tax



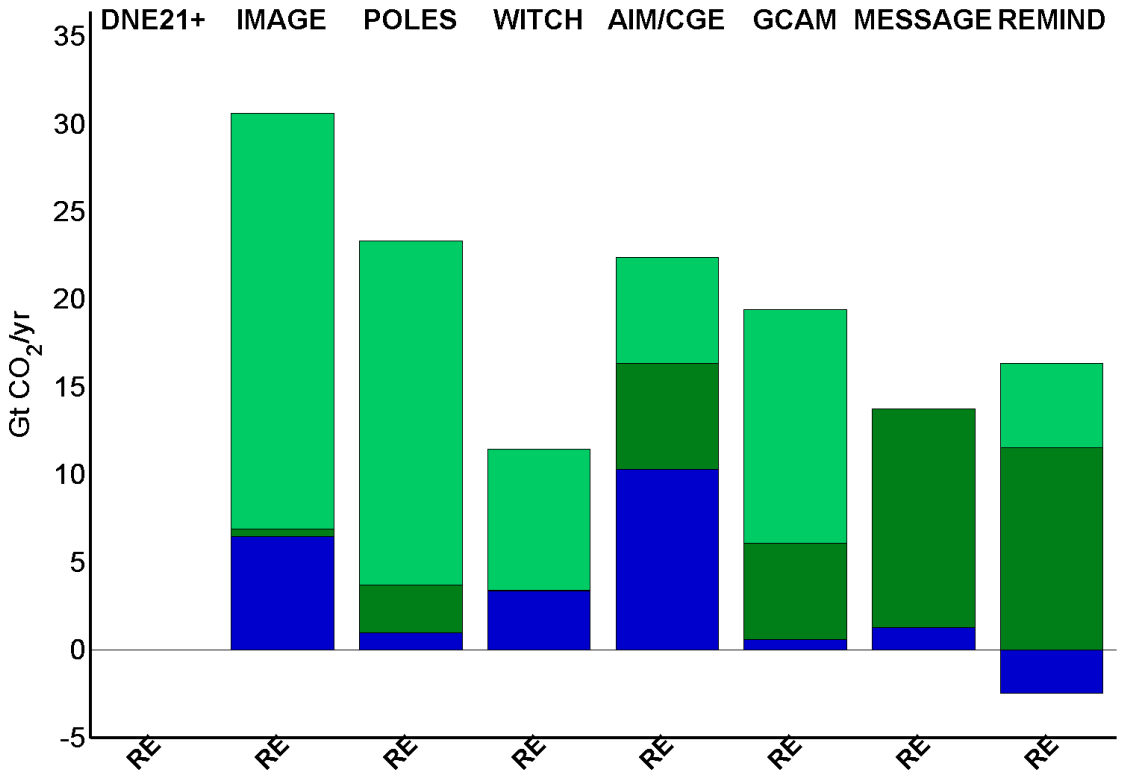
Global CO_2 Emissions by sector in 2050



Note: AIM/CGE did not report supply emissions.
Hence, correction applied.

- Significant increase in emissions (up to 17GtCO2 per year)
- Electricity sector is not necessarily largest
- BECCS to produce transportation fuel
- Demand sector emissions due to final energy substitution (less electricity)

Global CO_2 Emissions by sector in 2100

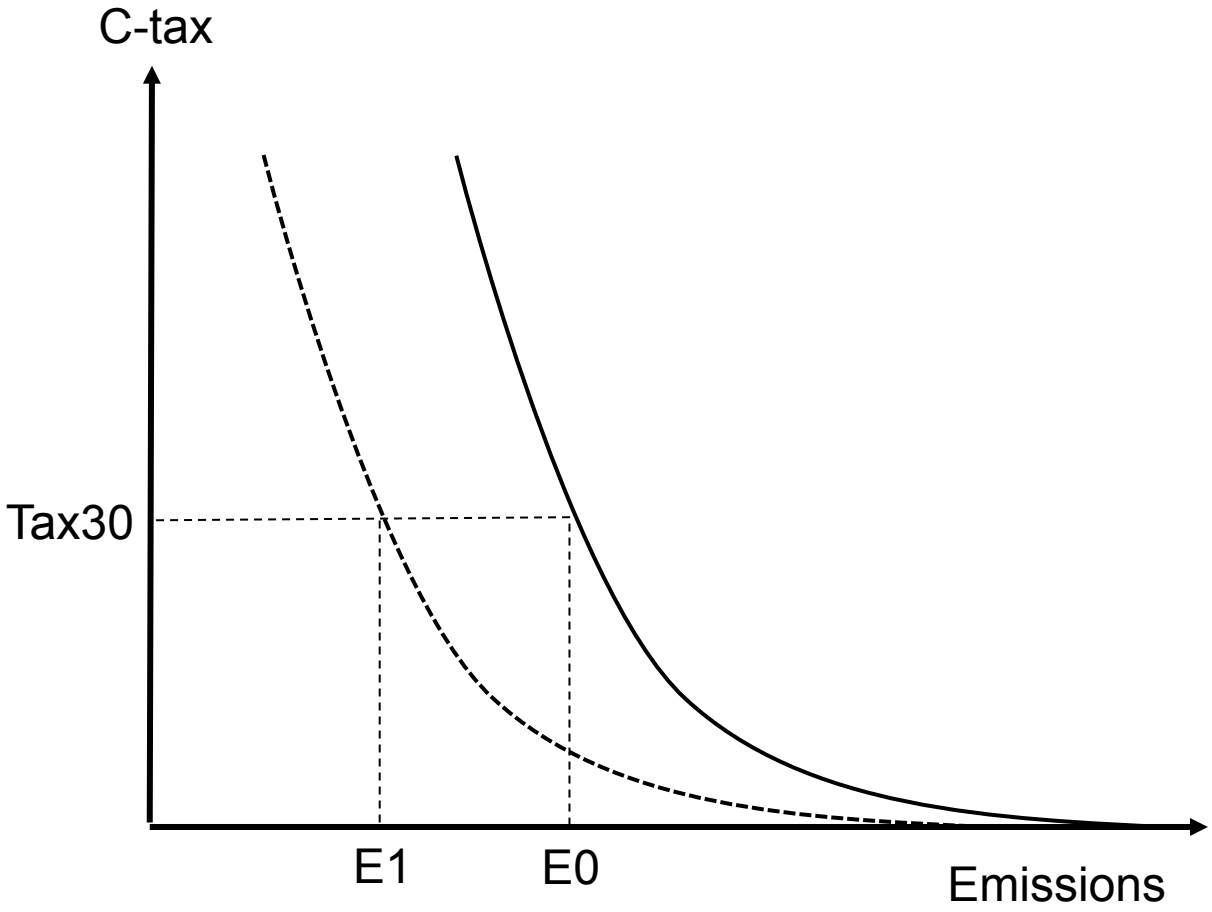


Note: AIM/CGE did not report supply emissions.
Hence, correction applied.

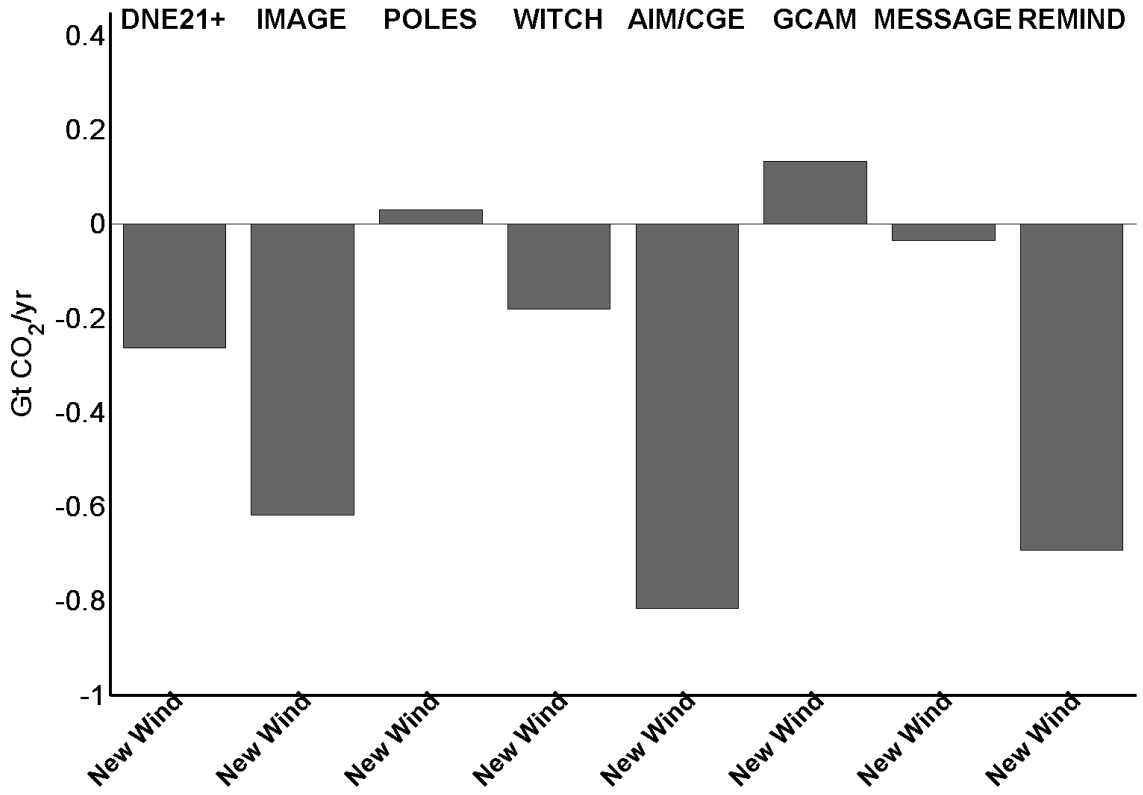
- IMAGE shows 30GtCO_2/yr emission increase; others around 15GtCO_2
- The additional emissions from non-electric sector are sometimes larger than those from electricity sector

The impact of New Wind in a world of fixed carbon taxes

Results – The Effect of New Wind

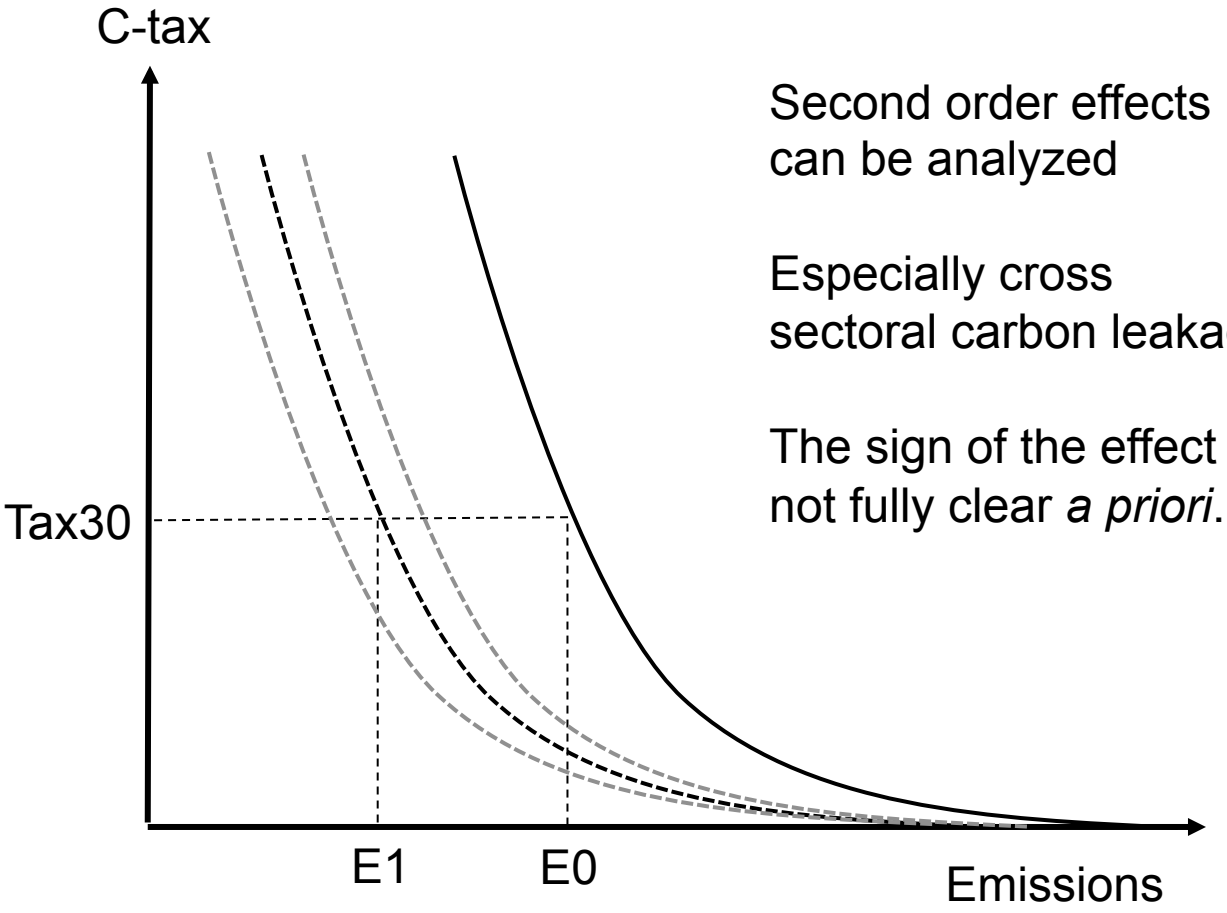


Differences in Global CO_2 Emissions in 2050



- On top of the tax, additional wind implies further emission reductions
- Up to 800MtCO_2 in 2050
- IMAGE's has lower C-tax ➔ more coal reduction ➔ more emission red.
-

Results – The Effect of New Wind

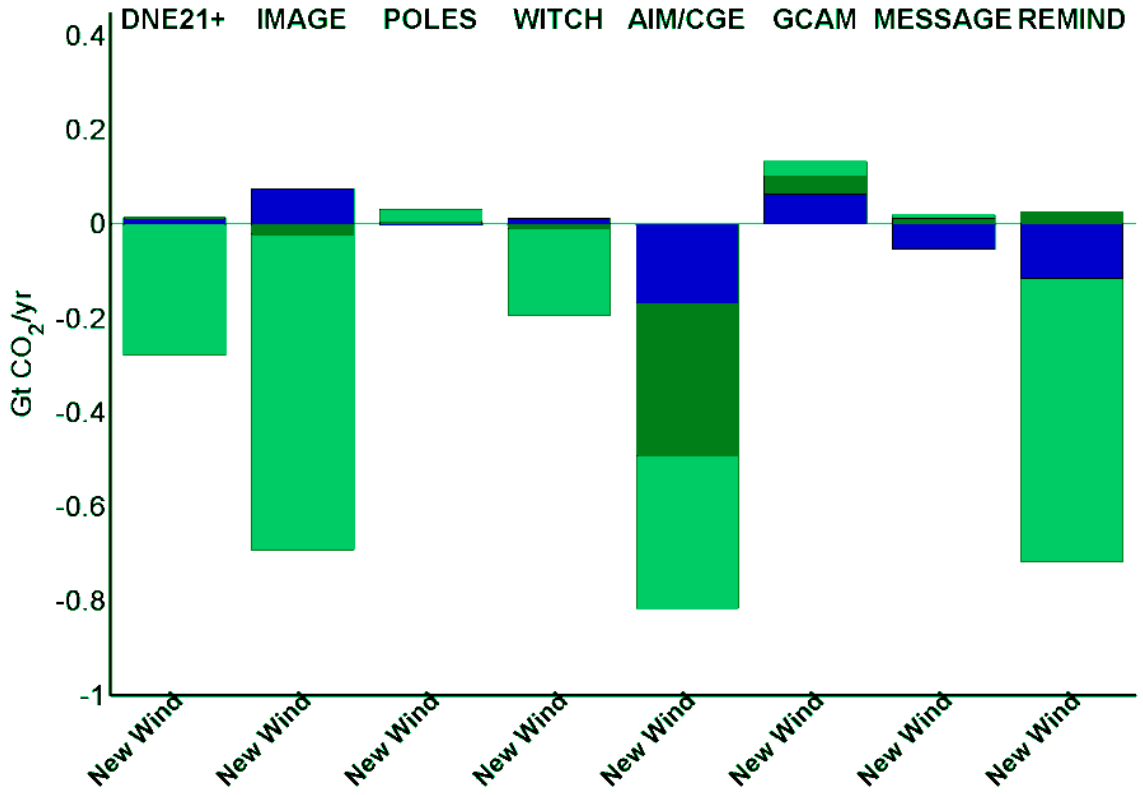


Second order effects can be analyzed

Especially cross sectoral carbon leakage

The sign of the effect is not fully clear *a priori*.

Differences in Global CO_2 Emissions in 2050

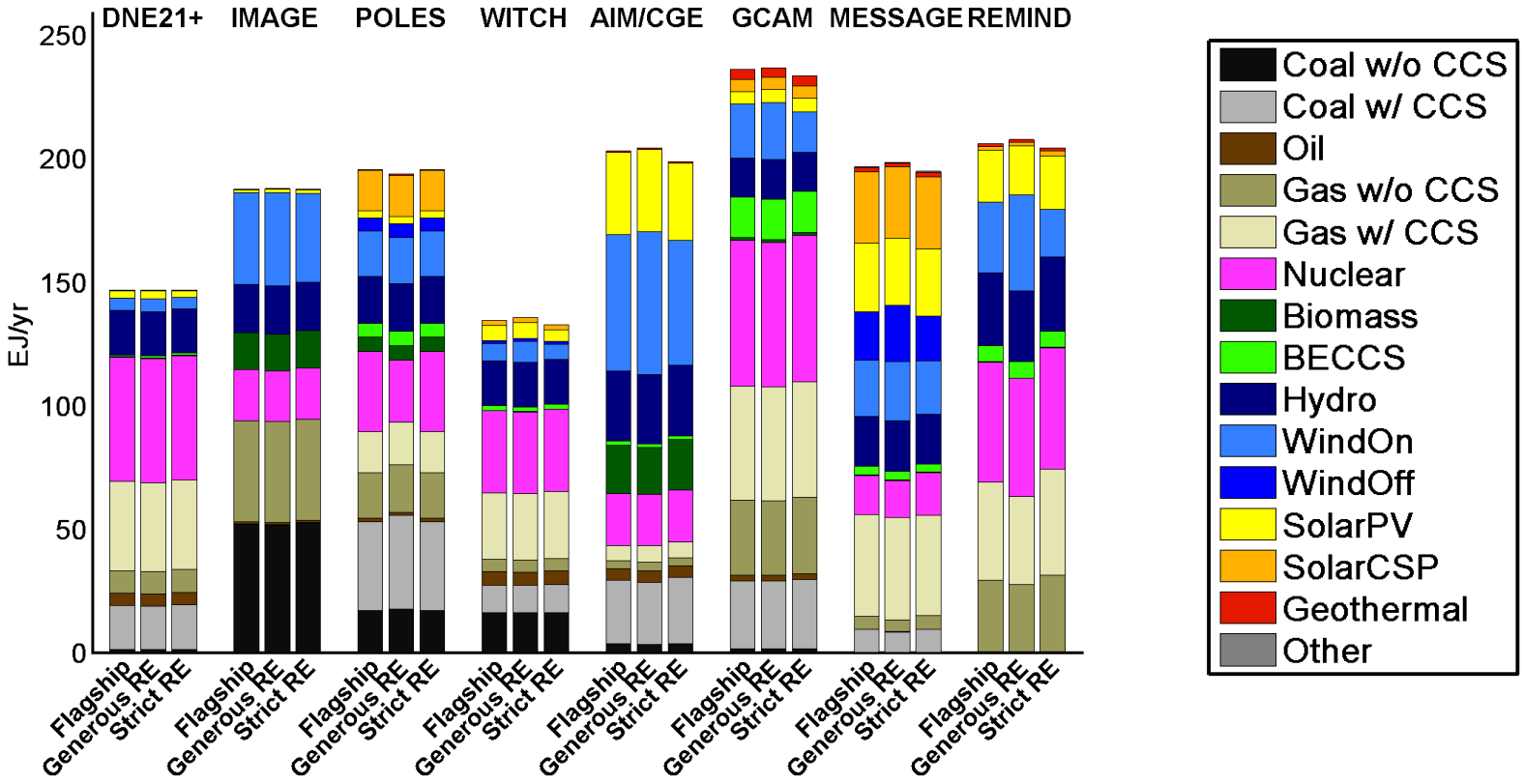


Note: AIM/CGE did not report supply emissions.
Hence, correction applied.

- Interaction with other sectors; sensitivity is not fully clear
- Additional wind electricity can
  - help substitute final energy from fossil (e.g. electricity in transportation)
  - Lead to intersectoral fossil fuel leakage

The impact of integration challenge in a world of fixed carbon taxes

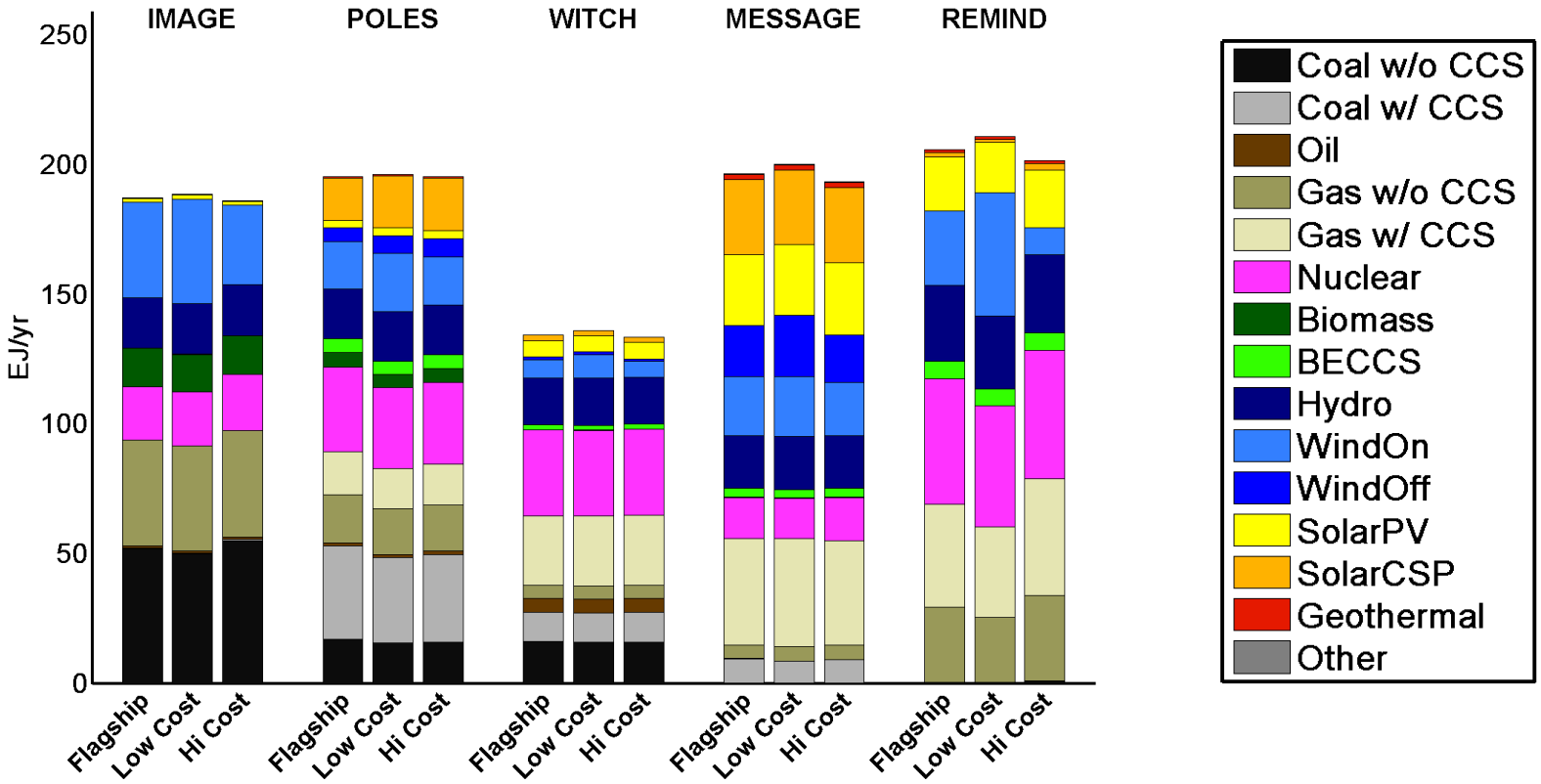
Global Electricity in 2050



- The sensitivity is rel. Small
- ReMIND substitutes gas by additional wind

The impact of investment cost changes in a world of fixed carbon taxes

Global Electricity in 2050

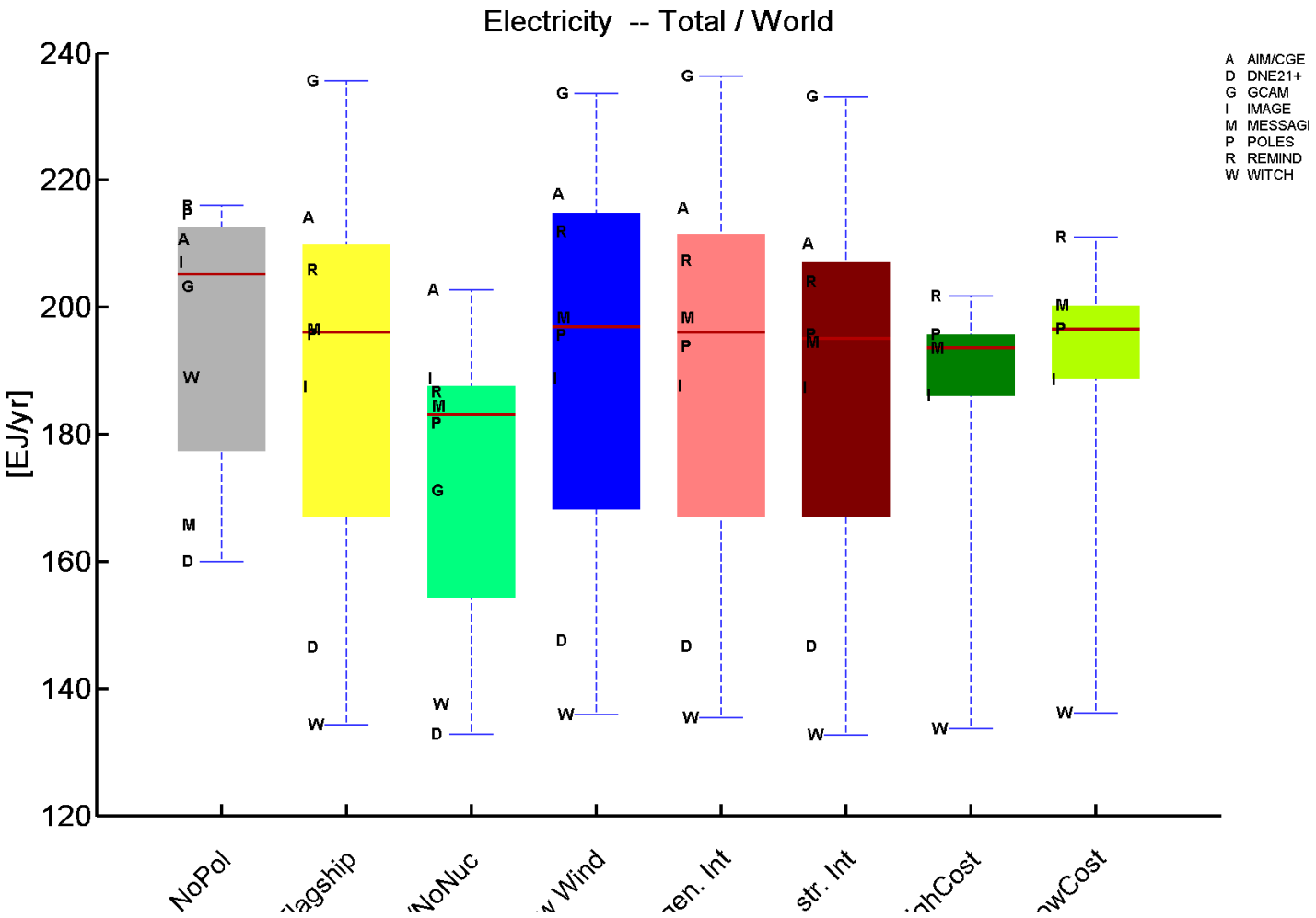


- The sensitivity is rel. Small
- Strongest impact in ReMIND (LCOE -33%/+45%); mainly gas substitution
- The effect on emissions is therefore also very limited; IMAGE coal effect

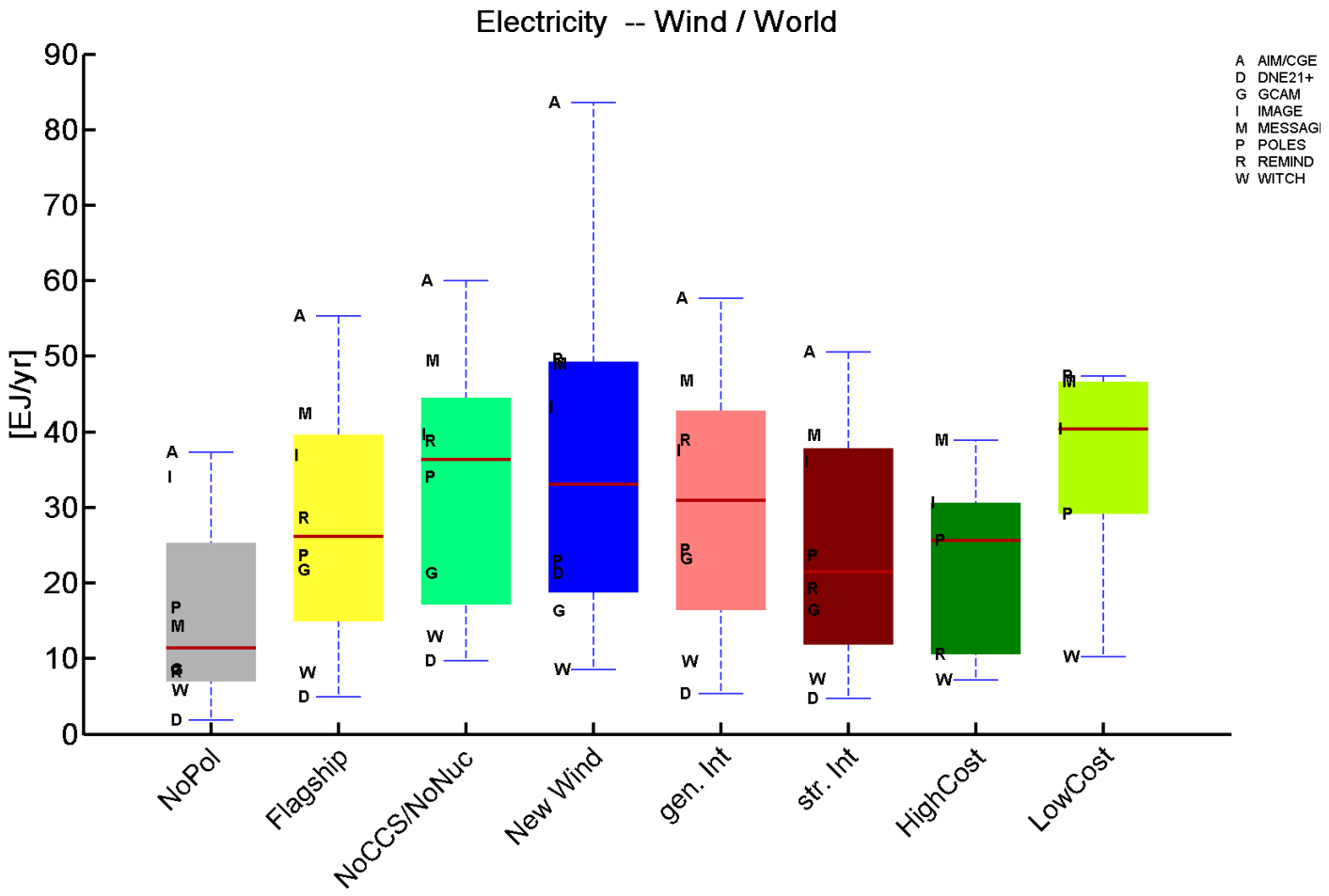
Summary

What are the key drivers for wind deployment and the impact on emissions?

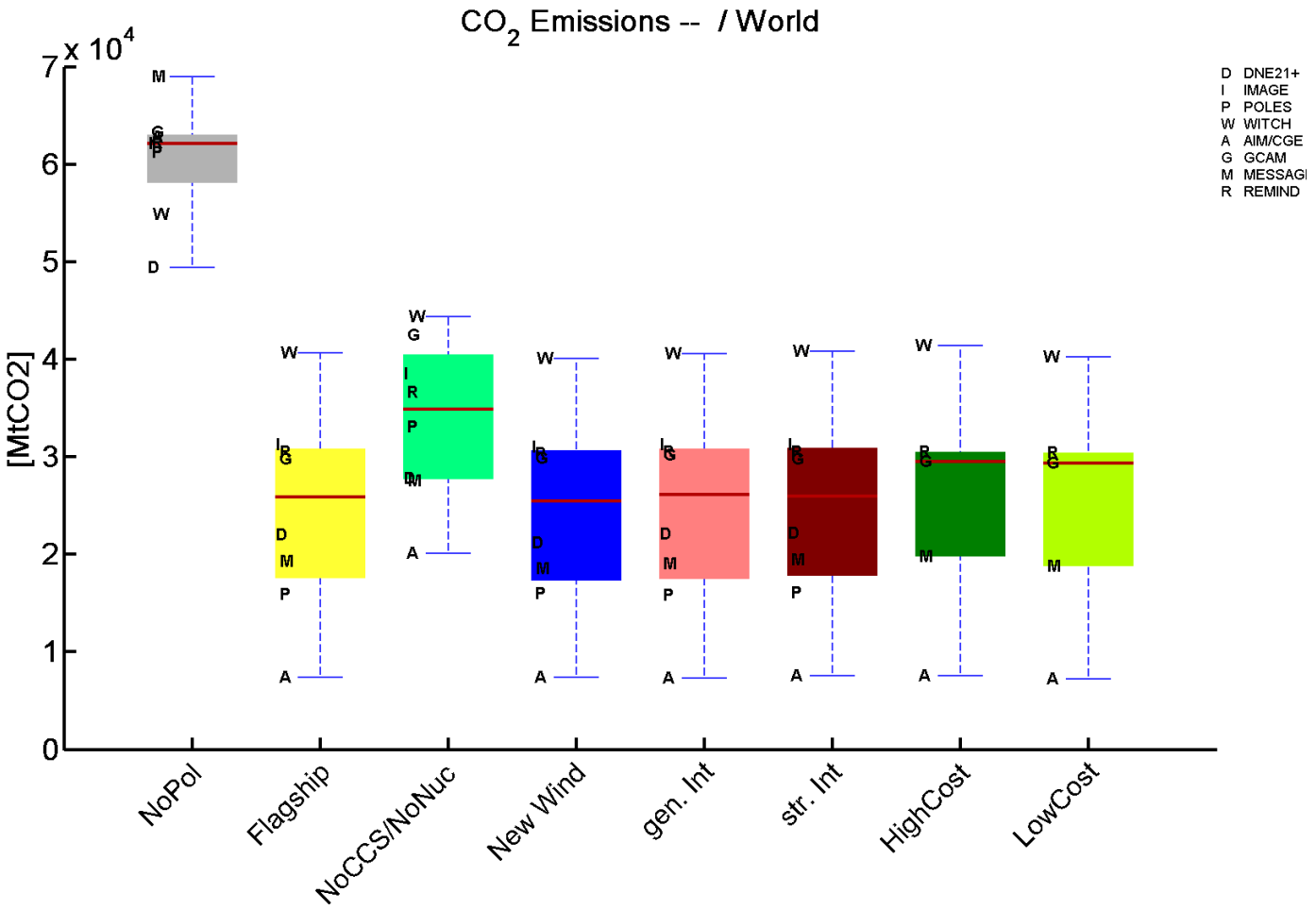
Summary – Electricity in 2050



Summary – Wind Deployment in 2050



Summary – Emissions in 2050



Further Questions

- What carbon policy should we set as a standard?
  - Prices vs. Quantities?
  - What level?

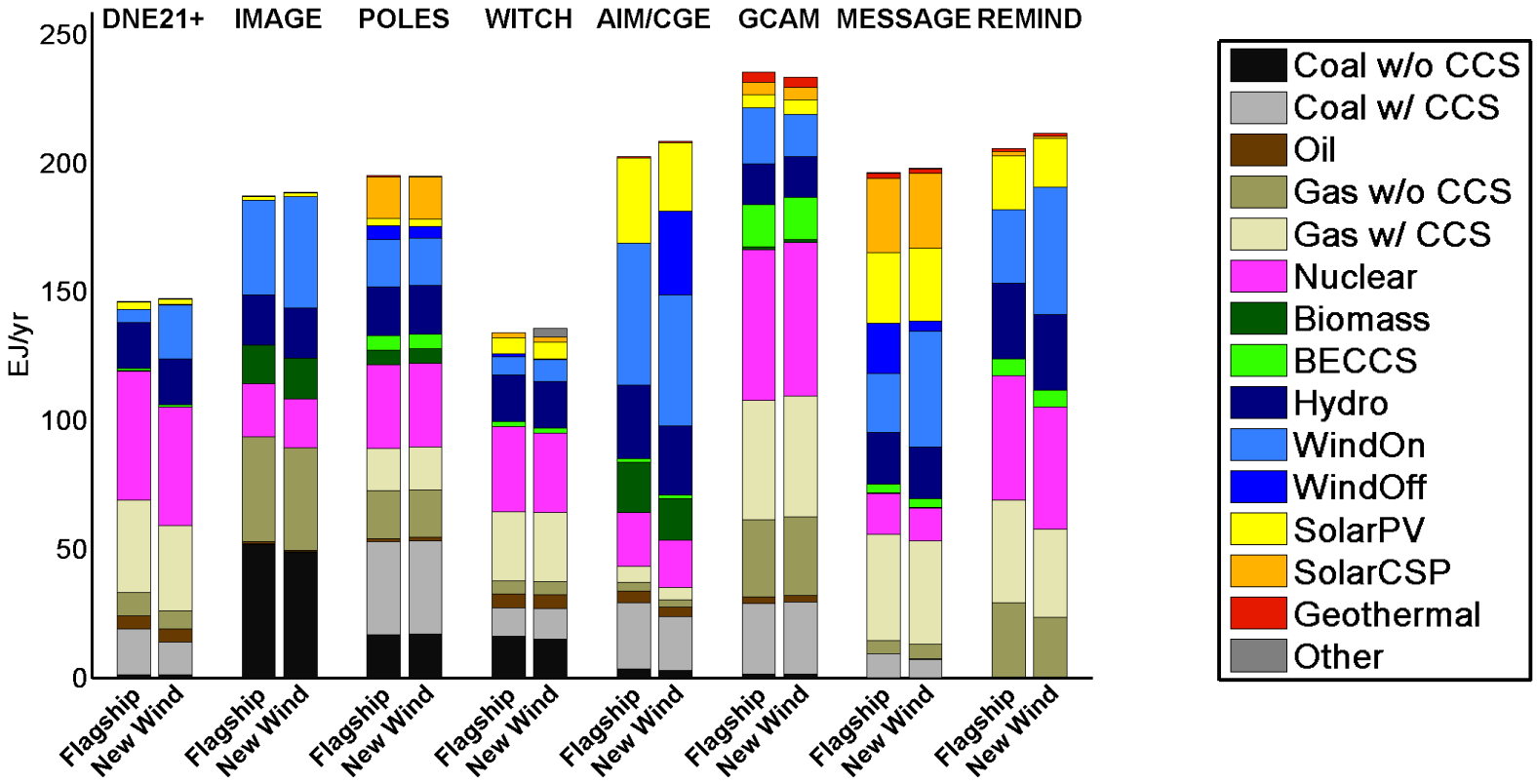
- Can we tell two (or more) consistent storylines for the electrifying and de-electrifying models? Also to derive the sensitivities in an economically consistent way?

- Can we see the noNuc/noCCS sensitivity as finished?

- How to set up a systematic uncertainty analysis of resource potentials?

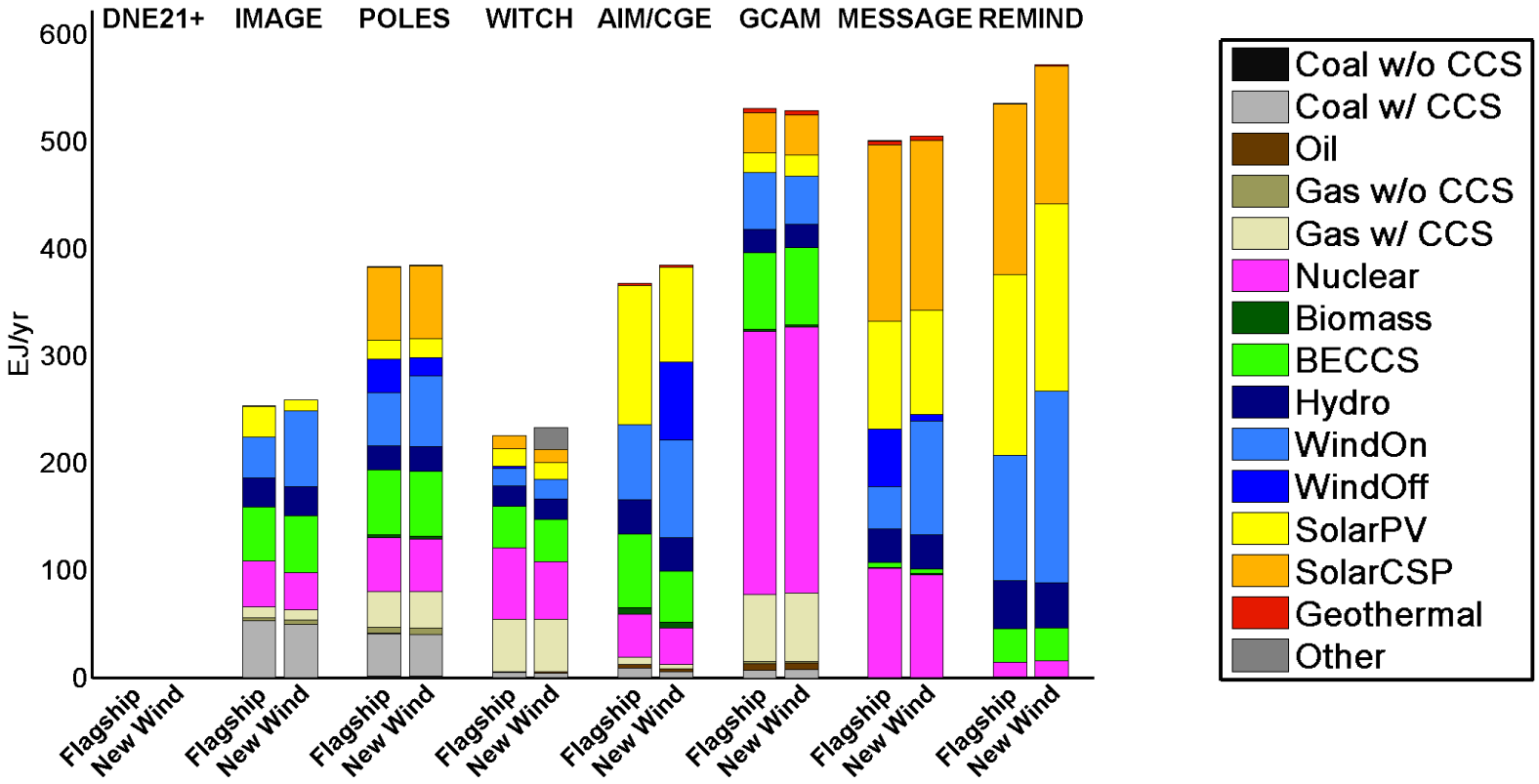
Additional Material

Global Electricity in 2050



- General effect: Structure dominates scale
- Models with reduced electricity supply, do not show boost
- High electricity models show small boost
- Additional wind competes with all supplies; also intra-wind and solar

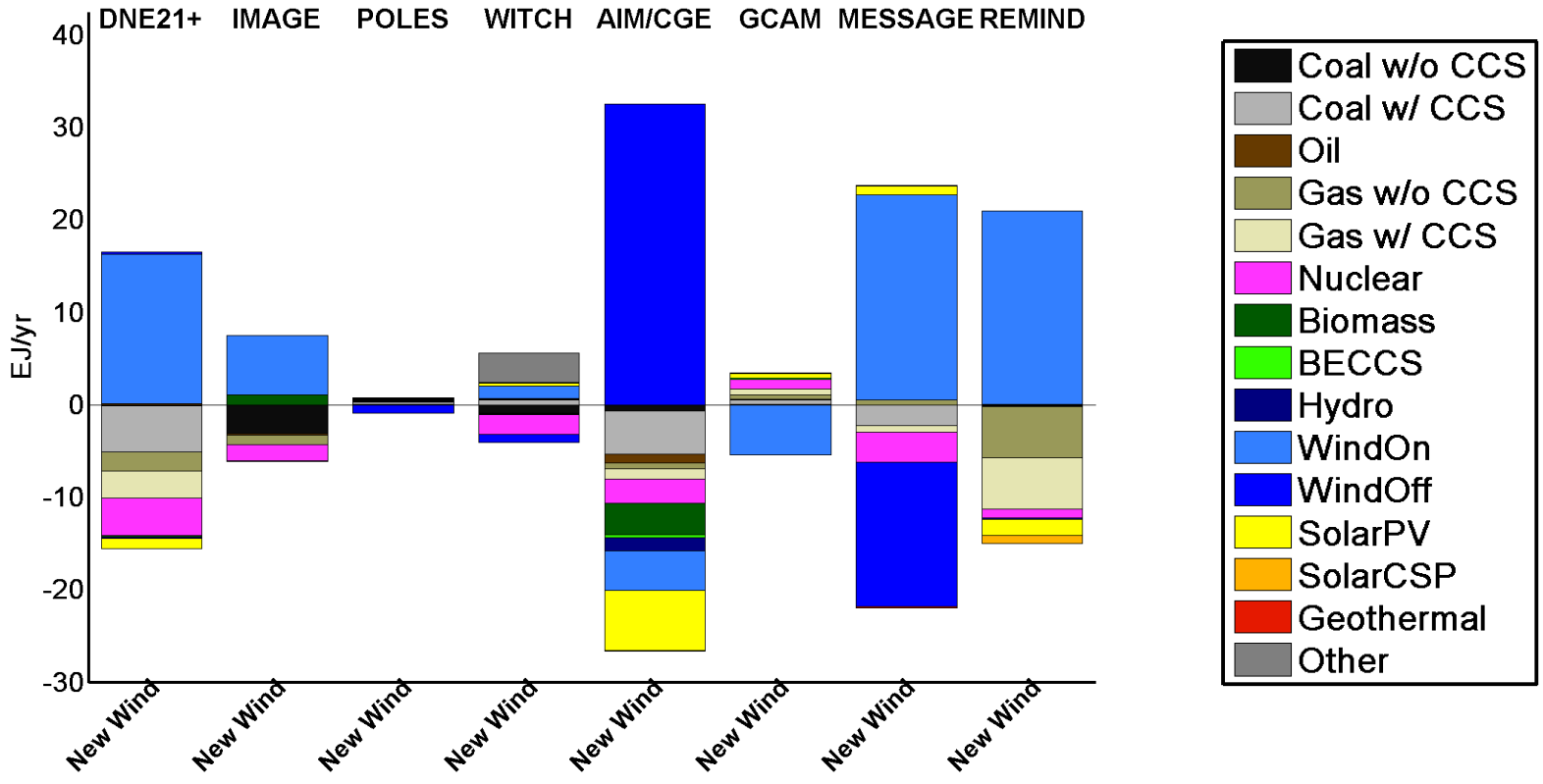
Global Electricity in 2100



- Additional wind grows over time (no saturation level approached earlier)
- In 2100 the effect on fossil generation is not so large any more, because there is not much left over

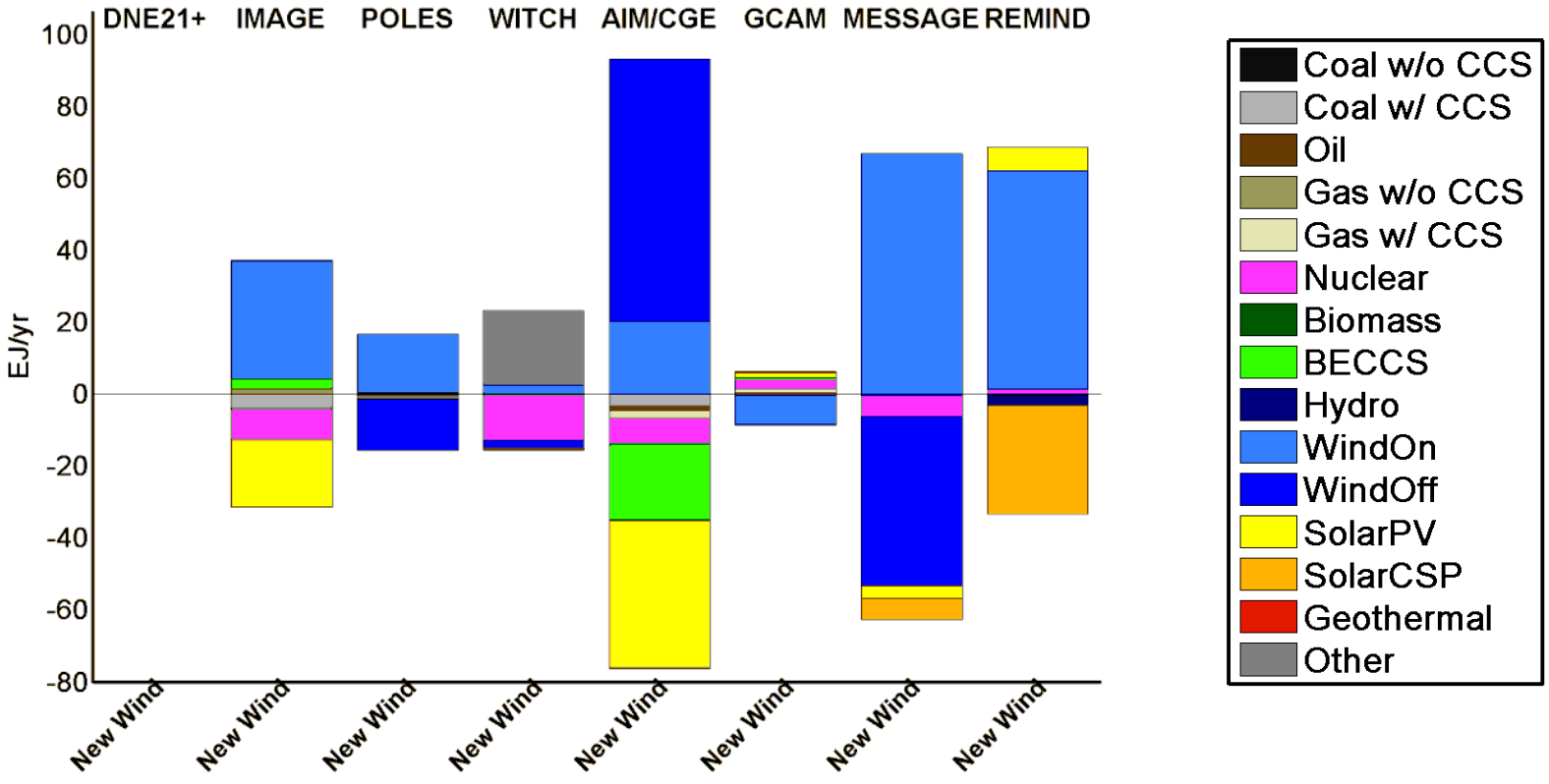
  ➔ The impact on emissions is more important in the near to medium term

Differences in Global Electricity in 2050



- Additional wind substitutes gas, coal CCS and nuclear
- Also solar is reduced (incl. CSP vs solar PV competition)
- Intra-wind competition is not clear (AIM/CGE and MESSAGE)
- More gas w/o CCS for backstop (MESSAGE)

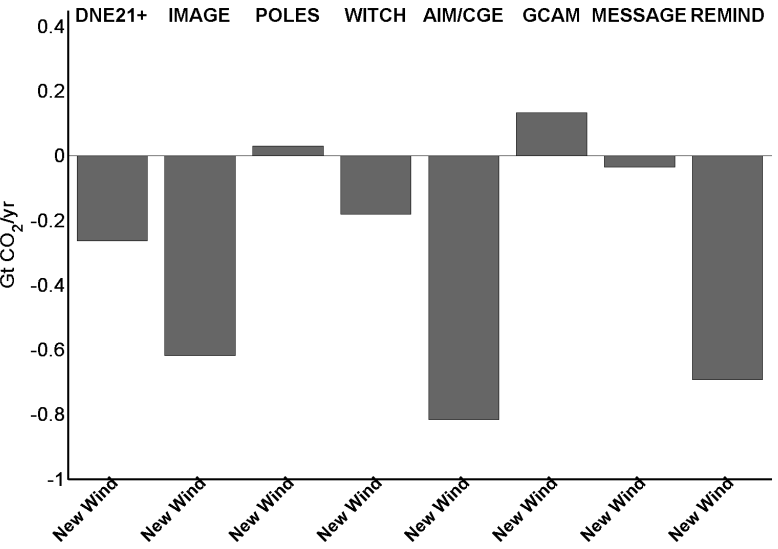
Differences in Global Electricity in 2100



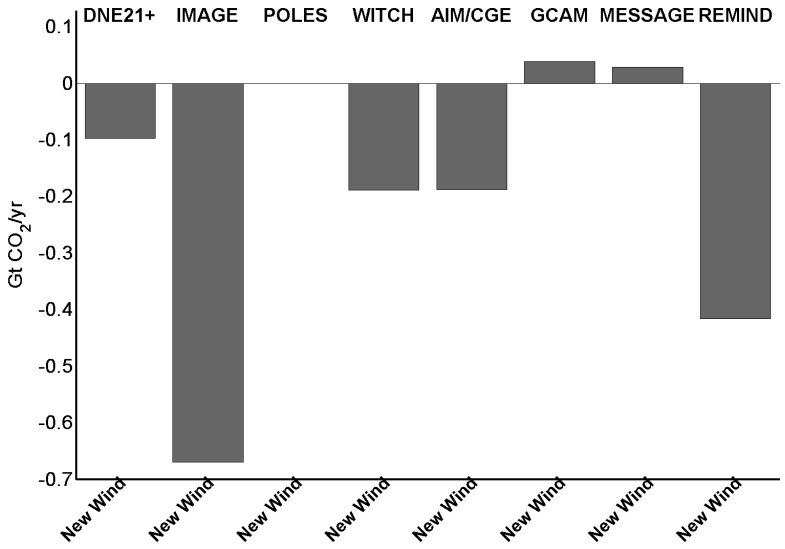
- Substitution mainly takes place among low-carbon technologies
- The scale effect still is positive, but the structure effect might only have negligible effects on CO_2 emissions

Results – The Effect of New Wind

Global in 2050



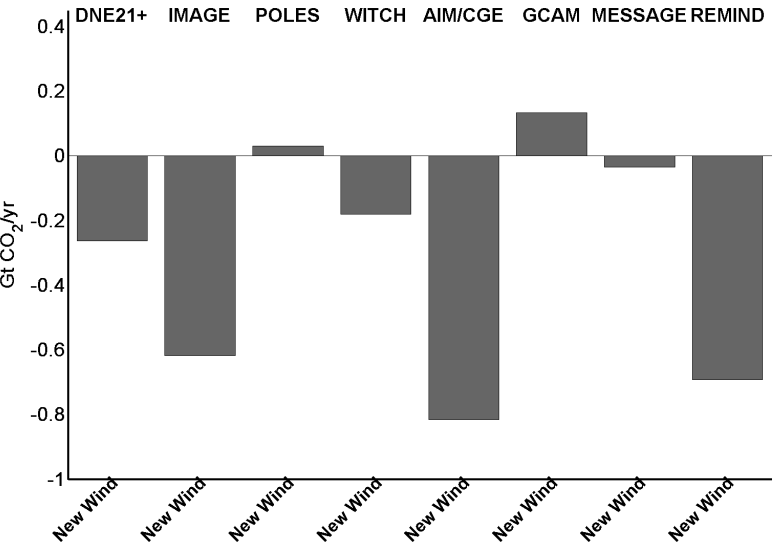
Asia in 2050



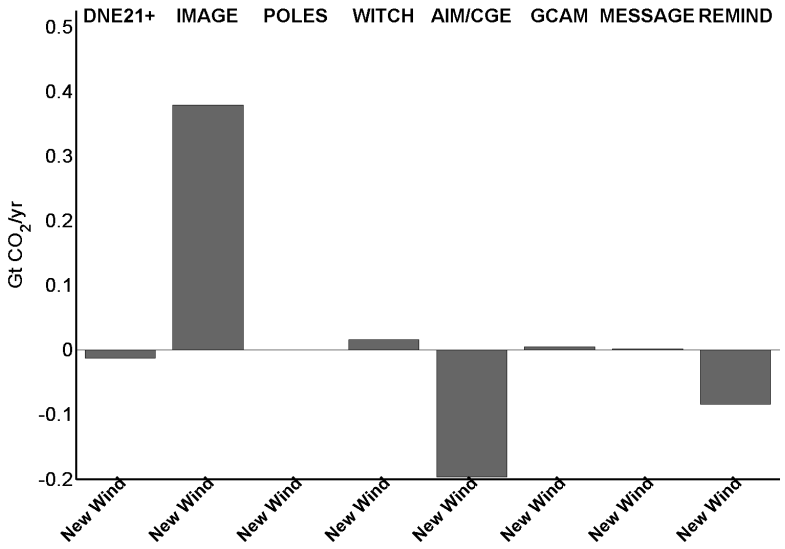
- The regional effects are highly diverse between models
- In Asia IMAGE and ReMIND show similar results, also WITCH and AIM/CGE

Results – The Effect of New Wind

Global in 2050



USA in 2050



- The regional effects are highly diverse between models
- In Asia IMAGE and ReMIND show similar results, also WITCH and AIM/CGE
- But in the US the two pairs are very different